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High Yield Possibilities.

The cover of this issue shows a picture of some ratoon cane. The plant cane preceding this crop yielded 118 tons of cane per acre and gave 15.83 tons of sugar per acre. We are not prepared to say whether the yield of the plant crop can be repeated in this, or subsequent ratoons. A great deal will depend upon the weather of the winter months and the influence that rains may exert on the quality of the cane.

An encouraging feature about these heavy crops of cane is that the methods used are simple, clear-cut, and applicable to other areas than those at Waipio—perhaps not to entire plantations, even when favorably situated, but to areas of considerable size having similar soil conditions and water supply. Such methods so applied should result in yields approaching in some measure the yields obtained at Waipio, even though the figures actually realized there are not duplicated.

A second encouraging feature about these heavy crops is that they were obtained from unselected H 109 cane and anything that bud selection has to contribute to the industry will express itself in still higher returns.

A third encouraging feature is that the variety H 109 may not be the best variety of cane which we have today for irrigated lands. An article in this issue by J. A. Verret shows that among the new seedlings we may have canes which are constitutionally superior. These seedlings, if better to begin with, will possibly lend themselves to improvement through bud selection.

The question arises quite naturally as to what is the physical limit to the amount of cane that can be produced on an acre of land. When do we reach the limitations possessed by an acre in point of sunlight and root zone? If these prove to be the limiting factors in sugar cane production, we must work for higher yields in terms of shorter cropping periods.

In other words, if we can not produce, without undue overcrowding and consequent rotting of cane in the field, more than 118 tons of cane per acre in two years' time, we must then work for yields of this character in less than two years' growing time.

A two year cycle may prove a less economical cropping period than it is

now held to be. If we can not produce three very heavy crops in six years, we must then seek to produce four heavy crops in the same length of time.

We may find, for example, that it is better business to produce four crops of 100 tons of cane in six years (or one crop each eighteen months) than to produce three crops of $133\frac{1}{3}$ tons in six years (or one crop each two years). The gross tonnage of cane in each case will be 400 tons per acre for the six year period, and possibly we shall be better able to control the quality of cane under eighteen month cropping cycles.

Looking ahead to yields of this type, it must, of course, be remembered that we are discussing our better irrigated lands and that even then the success of such agriculture is entirely dependent upon our ability to control insect pests and cane diseases, and that the loss of control of such factors would defeat what we may otherwise hope to accomplish. Between the industry and misfortune from pests and diseases there stand the accomplishments of our entomologists, plant pathologists, and quarantine officials. They must be given every support in the work that lies before them in preventing disaster to our plantations. We must also support the work of soil research that will determine how the heavy use of chemical fertilizers can be handled to best advantage under our one-crop agriculture.

Promising H 109 Seedlings.

1918 Oahu Propagation.

We report herewith the results of two harvests of a series of H 109 seedlings. The series comprises 102 varieties propagated in 1918.

The tassels from which these seedlings were obtained were collected at Ewa Plantation and at Waipio. Numbers 1 and 2 are from Ewa tassels with no other varieties growing nearby and are therefore probably pure H 109 seedlings. Numbers 48 to 55, both inclusive, are also from Ewa tassels. In this case Lahaina cane was in bloom not far away and we have possibilities of H 109 \times Lahaina crosses here. All the other seedlings are from Waipio tassels, where several other varieties were in bloom nearby, the nearest of which were D 1135, Striped Mexican, Lahaina, and some H 25.

In our work of seedling propagation, after handling many thousands of tassels, we have noted that we always get better germinations, and generally more vigorous seedlings, when we gather tassels from localities having two or more different varieties in bloom at the same time, than when we collect from the center of large fields of single varieties. This leads us to the conclusion that, when we gather tassels where several varieties are growing, the majority of the progeny obtained are crosses.

This point is rather well illustrated in the present series of seedlings. They

were obtained from a total of 885 tassels, giving 1480 germinations. Of these tassels 600 were from Ewa and 285 from Waipio.

The results obtained are shown as follows:

Lot No.	No. of Tassels	Where Obtained	Other Varieties Nearby	No. of Seedlings After First Selection
8	400	Ewa	None	2
14	200	Ewa	Lahaina *	8
9	150	Waipio	D 1135, Str. Mex.	45
16	25	Waipio	D 1135	12
18	50	Waipio	D 1135	7
2	60	Waipio	D 1135	28

* This Lahaina was on the makai side. The prevailing direction of the wind was from the H 109 towards the Lahaina.

Of the above seedlings the first two, from lot 8, are undoubtedly pure H 109. The eight from lot 14 contain some crosses, while of the remaining ninety-two the large majority are crosses between H 109 and one of the nearby varieties.

The first crop was planted on March 25, 1919, and harvested January 26, 1920. The second crop, first ratoons, was cut back for seed July, 1920, and harvested October 10-11, 1921.

In reporting these results we recognize the fact that it is not possible to determine the true value of a cane seedling with any accuracy until it has been cropped for at least five or six years, but since such a large number of these seedlings have given such uniformly high yields we feel justified in giving out at this time the results obtained. No other series of seedlings ever handled at the Station has produced such a high percentage of promising new varieties.

We are spreading these seedlings as rapidly as possible at Makiki and at Waipio, for which reason we shall not have seed for outside distribution for another year or two. At that time we shall have rather large areas for the distribution of those which continue to be high producers.

A number of these seedlings show a great resemblance to H 109. Number 49, for instance, is almost identical. It was grown from an Ewa tassel and is probably a pure H 109 seedling.

The results obtained are given below. The yields are reported from net areas. In comparing them to yields reported from irrigated plantations the amounts given should be reduced by 16% to allow for ditches and water courses.

Order of Sugar Yield in 1921 Crop	Number of Variety	Tons Cane per Acre*		Quality Ratio		Tons Sugar per Acre*	
		1920	1921	1920	1921	1920	1921
1	29	63.8	148.98	12.05	7.96	5.3	18.7
2	1	92.6	104.33	9.00	6.41	10.3	16.3
3	94	52.9	102.37	6.60	6.55	7.9	15.6
4	18	92.8	97.79	10.05	6.59	9.3	14.8
5	49	81.7	100.84	9.00	6.90	9.1	14.6
6	22	73.8	98.01	7.45	6.93	9.9	14.1
7	78	76.7	89.73	7.70	6.35	9.9	14.1
8	6	64.7	90.60	8.60	6.47	7.5	14.0
9	61	86.5	99.97	7.00	7.81	12.3	12.8
10	11	85.2	100.84	14.80	7.86	5.8	12.8
11	30	78.6	90.39	8.50	7.29	9.2	12.4
12	33	70.1	82.98	8.30	6.67	8.5	12.4
13	54	69.3	77.10	8.45	6.20	7.7	12.4
14	65	61.6	79.71	9.00	6.41	6.8	12.4
15	40	63.6	79.28	7.40	6.59	8.6	12.0
16	H 109*	56.6	75.36	7.55	6.29	7.4	12.0
17	88	59.9	78.84	6.85	6.67	8.7	11.8
18	10	77.1	143.75	9.95	12.16	7.7	11.8
19	82	52.3	75.58	7.05	6.47	7.4	11.7
20	47	68.0	72.96	9.10	6.30	7.5	11.6
21	27	62.7	84.07	12.55	7.24	5.0	11.6
22	12	71.0	90.60	9.00	7.98	7.9	11.4
23	2	81.2	80.59	11.45	7.09	7.1	11.4
24	45	54.2	72.75	10.15	6.44	5.3	11.3
25	19	54.9	81.68	7.70	7.44	7.1	11.0
26	13	65.6	73.40	6.60	6.81	9.9	10.8
27	48	66.9	70.13	7.70	6.53	8.7	10.7
28	17	68.2	71.00	10.15	6.72	6.7	10.6
29	39	61.4	69.48	9.60	6.62	6.4	10.5
30	46	66.9	72.53	10.40	6.91	6.4	10.5
31	25	55.5	84.94	9.85	8.07	5.6	10.5
32	55	62.9	83.20	9.95	8.02	6.4	10.4
33	67	61.4	67.95	7.45	6.61	8.2	10.3
34	98	49.4	70.35	7.45	6.80	6.6	10.3
35	7	86.9	88.21	13.70	8.53	6.3	10.3
36	63	63.2	71.87	10.15	6.95	6.2	10.3
37	36	55.8	71.87	8.15	7.04	6.8	10.2
38	76	59.2	68.82	7.25	6.89	8.2	10.0
39	87	56.2	70.35	8.85	7.07	6.3	10.0
40	85	42.9	65.78	6.80	6.67	6.8	9.9
41	43	62.1	71.87	12.55	7.29	4.9	9.9
42	72	43.8	70.13	10.05	7.09	4.4	9.9
43	4	84.5	81.89	9.45	8.32	8.9	9.8
44	52	73.2	58.81	6.80	6.07	11.5	9.7
45	93	59.2	67.30	8.95	7.12	6.6	9.5
46	21	65.8	76.45	8.90	8.11	7.4	9.4
47	H 109*	48.4	74.05	9.95	7.85	4.9	9.4
48	69	49.2	60.98	11.20	6.49	4.4	9.4
49	16	62.7	67.08	7.40	7.23	8.5	9.3

* These yields were not obtained under plantation conditions, and should be accepted for comparison purposes only. The juices were obtained from a small hand mill and are better than mill juices would be. A liberal discount should be made before comparing to plantation yields.

Order of Sugar Yield in 1921 Crop	Number of Variety	Tons Cane per Acre*		Quality Ratio		Tons Sugar per Acre*	
		1920	1921	1920	1921	1920	1921
50	92	48.1	70.57	7.35	7.61	6.5	9.3
51	51	49.5	64.90	10.90	6.98	5.5	9.3
52	83	49.0	62.51	7.25	6.82	6.8	9.2
53	53	55.5	57.72	8.05	6.39	6.9	9.0
54	8	58.6	60.77	11.20	6.81	5.3	8.9
55	90	55.1	59.46	8.00	6.76	6.9	8.8
56	79	38.6	63.38	7.30	7.17	5.2	8.8
57	97	59.9	57.06	8.05	6.55	7.4	8.7
58	38	58.2	76.23	8.45	8.80	6.9	8.7
59	58	78.2	60.77	8.15	7.07	9.5	8.6
60	96	50.3	52.27	8.45	6.08	6.0	8.6
61	102	67.3	52.71	6.15	6.20	11.0	8.5
62	28	83.4	76.88	11.60	9.17	7.2	8.4
63	37	66.4	76.01	12.20	9.00	6.2	8.4
64	H 109*	58.8	54.45	8.20	6.45	5.3	8.4
65	60	61.0	73.40	11.30	8.86	5.4	8.3
66	77	50.8	64.25	9.95	7.77	5.1	8.3
67	34	47.3	54.01	7.60	6.57	6.3	8.2
68	73	81.5	77.54	8.15	9.52	10.0	8.1
69	26	52.9	67.52	8.15	8.31	6.5	8.1
70	80	48.1	62.07	8.70	7.64	5.5	8.1
71	84	45.1	54.89	9.00	6.78	5.0	8.1
72	23	44.9	58.37	9.95	7.30	4.5	8.0
73	91	55.8	54.23	6.80	6.99	8.8	7.8
74	66	56.9	49.66	8.45	6.40	6.7	7.8
75	99	56.4	57.50	11.20	7.38	5.1	7.8
76	75	54.5	50.75	9.10	6.75	6.0	7.5
77	70	58.6	55.54	7.05	7.54	8.3	7.4
78	71	54.0	47.92	8.15	6.50	6.6	7.4
79	24	75.4	55.76	11.45	7.82	6.6	7.1
80	41	44.4	48.57	8.30	6.87	5.4	7.1
81	50	46.4	47.26	14.55	6.63	3.2	7.1
82	9	57.9	42.91	7.65	6.11	7.6	7.0
83	35	54.2	64.03	9.95	9.10	5.5	7.0
84	68	39.4	61.20	7.85	8.80	5.0	7.0
85	15	39.9	52.93	9.10	7.58	4.4	7.0
86	32	75.6	49.22	8.20	7.09	9.2	6.9
87	31	58.4	58.37	11.30	8.44	5.2	6.9
88	81	43.8	45.96	9.00	6.78	4.9	6.8
89	42	49.0	51.62	10.65	7.97	4.7	6.5
90	64	55.5	45.08	8.95	6.99	6.2	6.4
91	74	58.4	54.89	9.55	8.77	6.1	6.3
92	101	44.7	47.04	9.10	7.61	4.9	6.2
93	62	41.6	41.82	10.40	6.81	4.0	6.1
94	89	38.8	58.37	8.20	10.33	4.7	5.7
95	86	47.5	42.04	6.95	7.56	6.8	5.6
96	57	43.1	38.77	8.05	7.09	5.4	5.5
97	14	55.5	45.96	10.65	9.41	5.2	4.9
98	56	48.6	51.40	9.75	10.82	5.0	4.8

Order of Sugar Yield in 1921 Crop	Number of Variety	Tons Cane per Acre*		Quality Ratio		Tons Sugar per Acre*	
		1920	1921	1920	1921	1920	1921
99	100	60.3	37.24	8.15	7.96	7.4	4.7
100	3	47.5	29.62	10.90	6.52	4.4	4.5
101	44	47.9	38.55	11.75	8.70	4.1	4.4
102	95	35.7	32.89	11.05	7.69	3.2	4.3
103	59	42.7	37.90	15.00	9.42	2.9	4.0
104	20	43.1	35.72	8.00	9.52	5.4	3.8
105	5	43.8	30.71	14.35	8.71	3.1	3.5

* H 109 are outside rows.

J. A. V.

Wireworm Damage in Hamakua.

By O. H. SWEZEY.

The accompanying cuts were taken in one of the upper fields of the Hamakua Mill Company, near the forest line. The cane was planted in February of 1921, and the pictures were taken in the latter part of October. The thin stand of cane is chiefly due to the wireworms, they having been present at the time of planting, and having destroyed the eyes of much of the seed that was planted.

Wireworms were still present in the field at the time the photographs were taken, and could readily be detected by pulling up cane stools.

The investigations of wireworms by the entomologists in the fields at different times in the year, indicate that the most common species, *Monocrepidius exsul*, is developing at various stages all of the time; that is, larvae of various ages are to be found in the soil at whatever time of the year an investigation is made. They do not occur in distinct broods at definite times in the year. Wireworms collected in the field and cared for in the laboratory have grown to maturity in varying periods, some of them maturing to adult beetles all along during successive months, even up to a year and more. The adult beetles are attracted to lights at night. It has been noticed that at some times they are much more abundant than at others, as, for instance, once at Honokaa in the month of April.

Damage similar to that shown in the photographs was prevalent in fields of Paauhau Sugar Plantation Company, and at Honokaa Sugar Company, also last year. Much of the area planted in the spring required 10% to 50% of replanting if a full stand of cane was to be obtained. Some slight injury was found in a high field at Hawaiian Agricultural Company, Pahala, but the wireworms there were more numerous in trash than in the cane furrow. Wireworms were found very numerous in cane in Kona, but they had not caused a thin stand of cane in the field. They have not yet been found injurious in the cane



Figure 1.

Figures 1, 2 and 3. Photos taken in a mauka field of Hamakua Mill Co., showing thin stand of cane due to wireworm injury to the seed.



Figure 2.



Figure 3.

fields of the other Islands, though they are known to be present generally by the beetles being collected in the fields and forests, and also coming to lights, and the larvae are often found in the soil when digging for them, or are casually noticed when digging for other purposes. This species of wireworm being notably predacious on grubs and other insects in the soil and under trash, it has not caused injury to plants, except to sugar cane as above, in these few restricted localities.

The larger wireworm (*Simodactylus cinnamomeus*) is found much less frequently than the above species, but in August it was found to be the most prevalent species in one of the fields at Hamakua Mill Company. The work of this wireworm is somewhat different to that of the other more common one. Besides eating an eye or two, it burrows inside and eats a good deal around near the joint so that the seed is easily broken apart at the joints. It also burrows a good deal lengthwise in the seed, with the result that the seed is completely destroyed and soon rots.

The work of this wireworm is shown in Figure 4, where one seed shows eyes eaten out and other external injuries, and a lengthwise section of a seed shows burrows of the wireworm internally. This wireworm may be distinguished from the commoner one (*Monocrepidius exsul*) by examination of the posterior end, which is shown at IV in the figure. It is pointed, instead of being broad and armed with teeth as in *Monocrepidius exsul*, which is shown in Figure 3, page 2, of the *Planters' Record*, XXIII, July, 1920.

SEARCH FOR WIREWORM PARASITES.

F. X. Williams and C. E. Pemberton, in the Philippines and in Queensland respectively, have been searching the past few months for parasites, or other

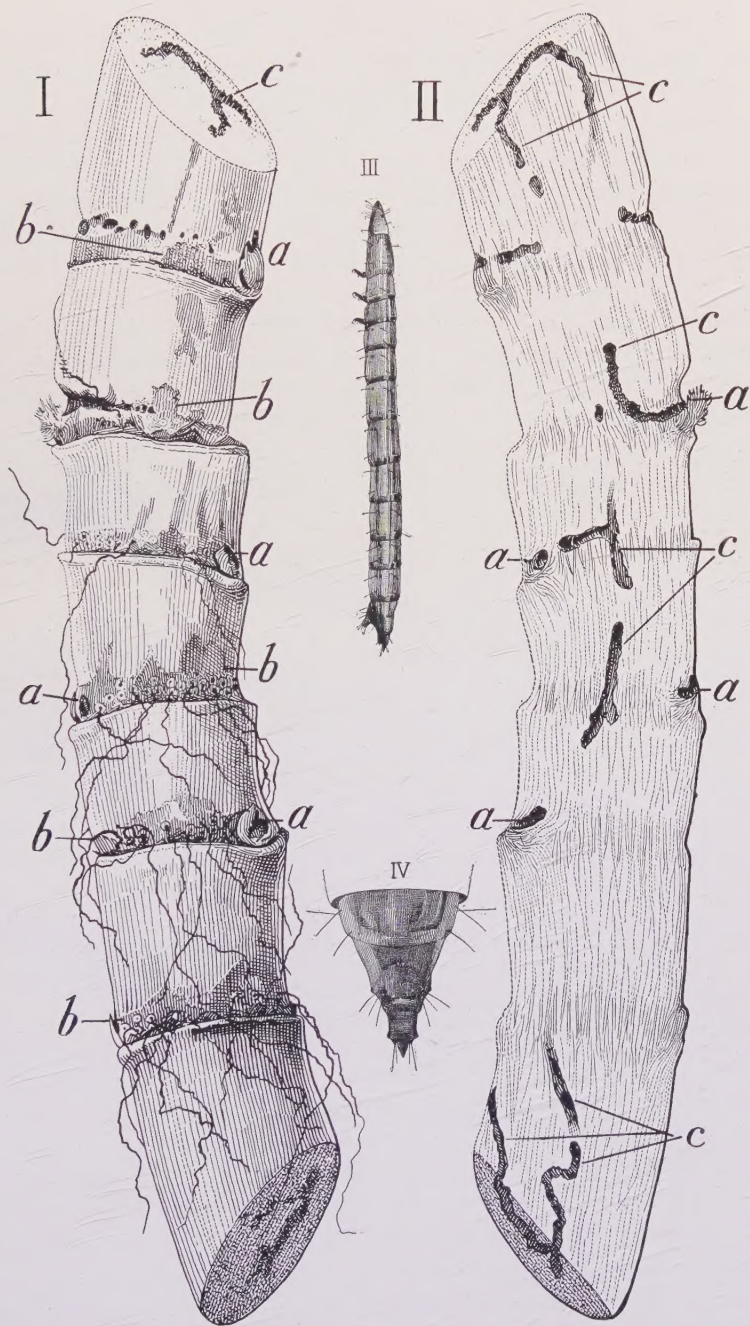


Figure 4. Wireworm injury (*Simodactylus cinnamomeus*).

- I. External view of seed showing wireworm injury.
- II. Lengthwise section of seed showing wireworm injury.
 - a. eyes eaten out.
 - b. Surface of rind and roots eaten away.
 - c. internal burrows.
- III. Wireworm twice natural size.
- IV. Posterior end of wireworm much enlarged.

enemies of wireworms which might seem practicable to introduce to Hawaii. Up to the present nothing of importance has been found, though Mr. Pemberton sent a mite which he found infesting wireworms in Queensland, and was occasionally fatal. As we have numerous species of mites here already in the soil and elsewhere, some beneficial and others detrimental, and as this one was not promising, it was not liberated. Mr. Pemberton also found a fungus on wireworms, but apparently of no importance. Mr. Williams has discovered a parasite on a small species of wireworm in the Philippines, but we have not yet received any of it to experiment with.

In literature, two or three records have been found of single cases where a wireworm has been parasitized, showing that scarcely anything is known of such parasitism. One case is of a parasite on a wireworm in Vermont. The parasite was known for a long time, described in 1828, and had been collected in Maryland, Virginia, Georgia, Florida and Texas, indicating a wide distribution in the United States, but the Vermont instance is the first that was known of its parasitic habit. If this parasite should be more fully studied, it might be found to be of some importance.

INSECTICIDES, REPELLANTS, ETC.

Experiments with several kinds of poisons and repellants were tried at Honokaa, but none of them proved of value. Much experimenting has been done in other parts of the world, but everything that is effective is either too expensive to be applied on a field scale, or impractical for other seasons.

One of the entomologists of the United States Bureau of Entomology, experimenting with sodium cyanide, has found that properly applied in the soil at the rate of 300 pounds per acre, it kills all the wireworms. At the same time it killed all of the corn plants in the field where the experiments were made. It was found also that even at the rate of 150 pounds to the acre all of the plants were killed. It is thus found that it cannot be applied where there is a growing crop in the field. It might be possible to use this fumigant in a cane field at the time of planting. If it did not injure the seed cane and did kill the wireworms, it would thus serve to free the soil of wireworms for the time and give the eyes time to germinate and get well started before another infestation of wireworms could occur. It would be worth while trying this the next time cane is to be planted in a wireworm section. At 65 cents per pound for the sodium cyanide the expense, however, would be rather high for practical purposes.

Phosphates in Hawaiian Soils—The Combinations and Their Availability.

A Preliminary Report.

By W. T. McGEORGE.

INTRODUCTION.

The role which the phosphate in Hawaiian soils plays in the nutrition of the sugar cane, while assimilated to a lesser extent than nitrogen or potash, is of considerable importance in fertilizer practices. We note from previous studies on our soils the presence of large amounts of this element, sufficient to support plant growth into an indefinite future. In spite of this fact, response is often obtained to phosphate fertilization and it is rarely omitted in the program.

Among the numerous fertilizer experiments conducted by the Station, certain areas have shown a distinct response to phosphate fertilizers, while in others no response was apparent. In order to add to our knowledge of the usual laboratory methods of studying the availability of phosphoric acid in our soils, an investigation of their relation to actual field tests has been made upon several such experimental plots.

METHODS OF ANALYSIS FOR SOIL PHOSPHATES.

GENERAL.

Methods for determining phosphates in soils may be definitely classified under four general headings: (1) Those for the determination of total P_2O_5 present; (2) extraction of soil with strong acids; (3) extraction with weak organic acids; (4) extraction with water and dilute solutions of mineral acids.

1. Methods for the determination of total P_2O_5 include fusion with a mixture of sodium and potassium carbonates, with sodium carbonate alone and decomposition with hydrofluoric and sulphuric or nitric acids, involving a volatilization of silica as silica tetrafluoride. While the data covering the total P_2O_5 in Hawaiian soils is meagre, the two latter methods have been found by experiment to be admirably adapted. A simpler method has been perfected in the laboratory involving fusion of the soil with sodium carbonate, extracting the completely disintegrated fusion with water, filtering and determining the P_2O_5 in the filtrate. The P_2O_5 goes in solution as sodium phosphate leaving behind the iron and alumina.

Of the total P_2O_3 determination by the above methods their value may be said to be limited yet definite. It eliminates the element of speculation that has accompanied the proposal of each new solvent as to its measure of the reserve or available P_2O_3 supply. The methods merit a more extended application to our soils. More particularly in their relation to acid soluble phosphates.

2. In strong acids we have a solvent for what Hilgard referred to as the "zeolitic reserve." In other words they should act as a measure of the permanent productive capacity of the soil. Strong nitric and hydrochloric are the acids which have received the most study, sulphuric being only lightly considered. Passing over the vast accumulation of data relative to extraction by these acids, suffice it to say that the factor of time and strength of acid vary between extremely wide limits and yield equally varying results. Hydrochloric acid gained the most favor in the old school of agricultural chemists and was finally adopted as an official method by the Association Official Agricultural Chemists. The designated strength was 1.115 Sp. Gr. and the time *exactly ten hours*. It has been generally assumed to be of value in determining the reserve supply of virgin lands. However, the recent changes instituted by the committee of the A. O. A. C. on revision of methods discredits this assumption. The facts are lacking which permit the drawing of any line of distinction between the so-called reserve and acid insoluble P_2O_5 . Strong acid extraction has therefore been dropped as an official method by A. O. A. C. and the total P_2O_5 by fusion is recommended.

Hydrochloric acid of Sp. Gr. 1.115 having been the official method over such an extended period it has been extensively used on local soils. These data may be said to be of considerable comparative value. Strong nitric acid has, however, been found to yield a more complete extraction and is given preference over hydrochloric in P_2O_5 determinations at this Station on account of the slightly higher result obtained thereby. Its greater value is open to question.

(3) Since it is now generally conceded that plant roots secrete no acids other than carbonic, the solvents of this class have gradually merged into class four and will therefore be treated with the weak acid solvents in use as a measure of the so-called available P_2O_5 . Claims regarding the simulation of plant root activities have been practically dropped.

(4) The attempt to distinguish between the available and non-available plant food produced a bewildering array of solvents by means of which attempts have been made to measure or classify that directly available to the plant. These include 1% citric, 1% aspartic, 1% oxalic, numerous strengths of nitric and hydrochloric acid solutions such as N/200, N/100, N/5, 1%, 2%, 4%, 8%, ammonium citrate, 1% acetic acid, 1% NaOH, distilled water, carbon dioxide saturated water, each accompanied by variations in time and temperature of extraction. In addition, the numerous attempts to separate the actual soil solution by centrifugal and pressure methods should be mentioned.

Investigations on local soil problems have involved the application of several of the above methods to Hawaiian conditions. These include 1% citric acid which was developed by Dyer, on English soils, on the theory that its use was confirmed by the acidity of root sap. Aspartic acid which was proposed by Maxwell on the supposition that the organic acids of the soil were amido acids, and N/5, N/200 hydrochloric acid, N/5 nitric acid and 1% sodium hydroxide which have been shown to exercise a selective solvent action on the soil minerals. The use of distilled water has also been practiced to a limited extent and is deserving of a more comprehensive study, as after all the plant is primarily at the mercy

of the solvent power of water containing varying amounts of CO_2 and aided by certain biological activities.

The extended use of 1% citric acid as a solvent for P_2O_5 in Hawaiian soils has resulted in the accumulation of much valuable data leading to its adoption as a means of measuring the available P_2O_5 .

DESCRIPTION OF SAMPLES.

Soil 364 is a sample of yellowish brown clay loam, virgin soil, from field 22, Experiment 9, Grove Farm, Kauai, and gave response to reverted phosphate.¹ Soils 375 and 378 are samples of a brown clay loam from Experiment 6, Grove Farm, Kauai, which gave no response to reverted phosphate applications.² Soil 398 is a yellow clay loam taken from Experiment 17, field 25, Kilauea Plantation, Kauai, which gave response to reverted phosphate applications. Soil 405 is a red clay loam from Experiment 2, McBryde Plantation, which gave no response to phosphates.³ Soil 1 is a sample of brown clay loam from Experiment V, Waipio Substation, which has given no response to phosphates.⁴ Soil 2 is a sample of red silty soil (manganiferous) from Experiment 6, field 45, Oahu Sugar Co., giving a distinct response.⁵ Soil 3 represents the Makiki experiment plots which do not respond to phosphates.

METHODS USED IN THIS WORK.

The methods used in the present investigation included determination of total phosphoric acid by decomposing the silicates with nitric and hydrofluoric acids;⁶ extraction with concentrated nitric and hydrochloric acids by the methods in regular use at this Station: extraction with 1% sodium hydroxide for five hours at the temperature of boiling water (1 part soil to 10 parts solvent); extraction with N/5 nitric acid for five hours at 40° C. (1 part soil to 10 parts solvent); extraction with 1% citric acid by the regular Station method. Several determinations were made using distilled water (1 part soil to 5 parts water), but on account of the high fixing power of the soil these were not extended.

The results obtained by these methods are given in the following table:

TABLE I.—SHOWING P_2O_5 AS DETERMINED BY SEVEN DIFFERENT METHODS.
(Moisture free basis.)

	Soil No.	Total P_2O_5	By Con. HNO_3	By Con. HCl	By 1% NaOH	By N/5 HNO_3	By 1% Citric	By H_2O
No response to P_2O_5	375	0.45	0.32	0.28	0.125	0.00044	0.0026	0.0014
	378	0.48	0.37	0.33	0.176	0.00058	0.0034	
	405	0.42	0.36	0.33	0.136	0.00121	0.0035	
	1	0.47	0.35	0.38	0.117	0.00048	0.0034	
	3	1.13	0.70	0.50	0.566	0.1628	0.3190	
Response to P_2O_5	364	0.36	0.23	0.19	0.066	0.00035	0.0012	0.00046
	398	0.49	0.16	0.25	0.118	0.00032	0.0009	
	2	0.28	0.13	0.16	0.048	0.00043	0.0024	

PHOSPHORIC ACID SOLUBLE IN STRONG ACIDS.

In general it may be said that the soils showing no response to phosphate fertilizers are higher in total and strong acid soluble P_2O_5 . Also that the ratio of strong acid soluble to total is higher. It appears from the above then that the ratio of strong acid soluble to total P_2O_5 is in a measure a function of its availability. Exceptions, however, are admitted and taken for granted.

This wide variation in the ratio of total P_2O_5 to acid soluble has been the incentive of several intensive studies of the problem. Veitch,⁷ in a series of analyses of Maryland soils found a variation of 4% to 100%, of the total P_2O_5 soluble in hydrochloric acid Sp. Gr. 1.115, the average being 57.6%. Similar determinations on Virginia⁸ soils showed a variation of 28% to 95% of the total to be soluble in this solvent. The data in Table I indicate less variation in Hawaiian types, being 44% to 81% (average 64%) for hydrochloric acid soluble P_2O_5 and 33% to 86% (average 64%) for nitric acid soluble P_2O_5 . Fry,⁹ in search of an explanation of the above, advanced two theories: (1) Either the P_2O_5 is present in the soil in compounds insoluble in acids, or (2) in such a form as to be protected from the action of the acids. The principal phosphates insoluble in acids include xenotime (yttrium phosphate), variscite (hydrated aluminum phosphate), and lazulite (hydrated iron, magnesium, aluminum phosphate). The mineralogical analyses by the Bureau of Soils have, however, never shown the presence of these minerals. But examination has disclosed the presence of acid soluble P_2O_5 enclosed in quartz grains, from which he concludes that the latter is the principal factor.

The results given in Table I apparently militate against such conclusion applying to local soils, more particularly our clay types. Less variation in ratio of acid soluble to total P_2O_5 , presence of large amounts of comparatively insoluble iron, aluminum and magnesium in the acid insoluble residue; environment conducive to hydration; the lower ratio of acid soluble to total P_2O_5 in the yellow soils which are in a state of greater hydration than the red clay or brown types; and the higher P_2O_5 content of clay and fine silt as compared to the coarser particles in Hawaiian soils, all point toward the presence of highly insoluble phosphate compounds.

PHOSPHORIC ACID SOLUBLE IN DILUTE MINERAL ACIDS AND ALKALI.

One per cent sodium hydroxide and N/5 nitric acid have been extensively used as solvents for basic iron and aluminum phosphates and calcium phosphate, respectively. Stoddart¹⁰ has shown that the basic phosphates of iron (Dufrenite $Fe PO_4 Fe (OH)_3$) and aluminum (Wavelite $Al_6 (OH)_6 (PO_4)_4$) are 90% soluble in 1% sodium hydroxide at the temperature of boiling water. Fraps¹¹ found that calcium phosphate and the precipitated or normal iron and aluminum phosphates are practically 100% soluble in N/5 nitric acid at 40° C. We have here then selective solvents which, allowing for the fixative properties of the soil, should yield information regarding the forms in which the P_2O_5 exists.

Table I shows the preponderance of basic iron and aluminum over the calcium and normal iron and aluminum phosphates. This fact, however, merely confirms previous investigations^{12 13} on local soils. It should be noted that the

soils giving no response to phosphate fertilization are higher in P_2O_5 soluble in these solvents.

Other than as a measure of basic iron and aluminum phosphates 1% sodium hydroxide has found little application. That is, no attempt has been made to establish a relation between results obtained by this solvent and field tests. On the other hand several of the state experiment stations have developed more or less comprehensive relations between the P_2O_5 soluble in N/5 nitric or hydrochloric acids and response to P_2O_5 fertilization. Peter and Averitt¹⁴ at Kentucky find a close correlation between field tests and phosphoric acid soluble in N/5 nitric acid. Snyder¹⁵ at the Minnesota Experiment Station, in studying a series of plots the soils of which ranged in N/5 nitric acid soluble P_2O_5 from .0025% to .0650%, found that all plots showing .0025 to .0083 gave a response to phosphates, while in all cases above .015% no response was obtained. Fraps¹⁶ at the Texas Station concludes from pot experiments that soils containing less than .0020% P_2O_5 soluble in N/5 nitric acid are highly deficient, those between .002% and .010% are usually deficient. Stoddart¹⁷ claims a response to phosphate fertilization on Wisconsin soils showing less than .015% P_2O_5 soluble in N/5 nitric acid. Kelley¹³ found that Indiana soils, with few exceptions, showing less than .01% P_2O_5 soluble in N/5 hydrochloric acid respond to soluble phosphates. On later applying this solvent to Hawaiian soils only a trace of P_2O_5 soluble in N/5 hydrochloric acid was found in those soils giving a response of phosphates.

PHOSPHORIC ACID SOLUBLE IN 1% CITRIC ACID.

Citric acid as a solvent for available plant food was put forth by Dyer¹⁸ and has been extensively studied in England, where a more or less satisfactory working agreement has been established between its solvent action and field tests. It is not, however, assumed that 1% citric acid simulates any root secretion or is an absolute measure of available P_2O_5 . On applying intensive tests on known Rothamsted soils, Hall¹⁹ reached the conclusion "that no line of distinction can be drawn between available and non-available compounds in the soil. That is, no group of compounds is always available under all conditions before others are attacked." Available P_2O_5 , as measured by dilute acid solvents, depends on the coefficient of solubility possessed by the acid and proportion of different phosphate compounds present. Of the solvents used in his investigations he favored 1% citric. Fraps¹⁶ has shown that the solvent action of citric acid is similar to that of N/5 nitric acid except that the latter is a stronger solvent for calcium phosphate minerals. The precipitated phosphates of iron, calcium, and aluminum are practically completely soluble in both solvents, while the basic phosphates are practically insoluble. N/5 nitric acid yields higher results on Texas soils than 1% citric. Our results, however, confirm those of the English investigators, Hall and Amos, at Rothamsted, in that the citric extracts the more P_2O_5 .

Referring to Table I, it will be noted that in all cases a higher citrate soluble P_2O_5 content is noted in the soils giving no response. Furthermore, the ratio of total to citrate soluble is higher, with the exception of the highly man-

ganiferous type, sample 2. Comment on the above is reserved for further discussion.

As a whole the data given in Table I, coupled with the investigations of other experiment stations covering the various methods of measuring the P_2O_5 needs of the soil, indicate that, regardless of method or solvent used, individual variations from the average being admitted, higher results will be obtained on those soils giving no response. It appears from the accumulated data where this problem has been extensively investigated that a working correlation is possible through a judicious choice of the most suitable solvent extensively applied and supplemented by actual field tests. Due consideration must, however, be given to the complexity of the limiting factors which influence the variations from the rule, some of which will be treated later. Data in Table I indicate 1% citric to possess advantages as a solvent admitting of its choice as such.

In the report of the Director of this Station of January 6, 1921, a suggested correlation between citrate soluble P_2O_5 and soil needs gives .004% as a point above which our soils are not apt to respond.

FACTORS INFLUENCING P_2O_5 DISSOLVED BY 1% CITRIC ACID.

In view of the extended period over which citric acid has been used at this Station and the correlation suggested as a working agreement, several factors which have been heretofore ignored appeared to warrant attention. What portion of the citric acid is neutralized during the course of the extraction, and should allowance be made for this? Are Hawaiian soils capable of fixing P_2O_5 when in contact with dilute acid solvents? What is the effect of repeated extractions with citric acid? That is, what proportion of the citrate soluble P_2O_5 is dissolved by one extraction?

ACIDITY NEUTRALIZED.

Table II shows the acidity neutralized by the soil bases during extraction, original acidity being 1 gm. per 100 cc. for the citric extracts and 1.3 gm. per 100 cc. (approx. N/5) for the nitric acid extracts.

TABLE II.
SHOWING RELATION BETWEEN AMOUNT OF CITRIC (ORIG. 1 GM. PER 100 CC.)
AND NITRIC (1.3 GM. PER 100 CC.) ACIDS NEUTRALIZED IN EXTRACTION.

Soil Number	No Response to P_2O_5					Response to P_2O_5		
	375	378	405	1	3	364	398	2
Nitric Acid gms. neutralized	0.233	0.202	0.151	0.126	0.466	0.089	0.082	0.138
% HNO_3 neutralized ...	18.0	15.5	11.2	9.3	35.2	6.85	6.45	10.5
Citric Acid gms. neutralized	0.141	0.180	0.676	0.196	0.595	0.572	0.480	0.736
% Citric neutralized	14.4	18.5	69.0	19.6	55.8	58.6	49.3	73.6

It will be noted that the activity of citric acid toward the soil bases exceeds that of nitric acid of equal strength. This offers an explanation of the greater solvent action toward phosphate compounds. Alumina, lime and manganese, especially the latter, are the primary factors in the degree of neutralization.

The relation between the degree of neutralization and P_2O_5 dissolved as given in Table III does not indicate any relationship of value.

TABLE III.
SHOWING RELATION BETWEEN CITRIC ACID NEUTRALIZED
AND P_2O_5 DISSOLVED.

Soil Number.....	375	378	405	1	3	364	398	2
% Acid Neutralized....	14.4	18.5	69.0	19.6	55.8	58.6	49.3	73.6
% Citric Sol. P_2O_5	0.0026	0.0034	0.0035	0.0032	0.297	0.0012	0.0009	0.0022

In order to throw further light upon this question, soil samples 1 and 2, representing the two extremes, were extracted with 1% citric acid in which allowance was made for that neutralized. Results obtained thereby checked with those in which no such allowance was made. It is therefore not deemed necessary to make any allowance for the acidity neutralized by the soil bases. This is probably due to the low carbonate content of Hawaiian soils in that practically none of this acid is used in neutralizing carbonates.

SUCCESSIVE EXTRACTIONS.

Hall and Amos²⁰ in studying the solvent action of dilute acids on soils devoted some time to an investigation of the P_2O_5 extracted by successively attacking the soil with the solvent. In other words they desired to know what portion of the citrate soluble P_2O_5 was removed in one extraction. Fraps¹⁶ has made a similar study on Texas soils using N/5 nitric acid.

Table IV gives the results obtained by three successive extractions with 1% citric acid on soils 1 and 2. Extractions were made by the regular method, the soil being washed twice with distilled water between extractions.

TABLE IV.
SHOWING SOLVENT ACTION OF SUCCESSIVE EXTRACTIONS WITH
CITRIC ACID.

Soil No.	% Acid Neutral- ized	P_2O_5	SiO_2	Fe_2O_3	Al_2O_3	Mn_2O_4	CaO
1	19.6	0.0032	0.180	0.055	0.132	0.237	0.164
1	14.7	0.00017	0.063	0.027	0.026	0.062	0.043
1	10.8	0.000014	0.059	0.019	0.015	0.027	0.024
2	73.4	0.0022	0.096	0.142	0.434	1.212	0.192
2	29.4	0.00015	0.063	0.049	0.145	0.327	0.046
2	19.6	0.00003	0.055	0.038	0.087	0.172	0.024

These data suggest two possibilities: either the fixing power of the soil is very high, or the amount of citrate soluble P_2O_5 is low and completely removed in one extraction, the low subsequent extraction being due to the highly insoluble form of the residual P_2O_5 . While there is ample proof that the latter is a factor of no small importance in this phenomenon, as yet we have no data on local soils covering fixation by the soil subsequent to solution, or in the process of formation of equilibrium between soil and solvent. Hall and Amos²⁰ found a gradual decrease in P_2O_5 with successive extractions, becoming practically constant after the fifth or sixth. It is of interest to compare these results with local soils, in which a constant figure is obtained in two or three extractions. Thus the evidence indicates that, for Hawaiian soils at least, the action of 1% citric acid is a simple solvent action removing in one extraction the most soluble phosphates in their entirety, exclusive of course of that portion absorbed by the soil in the process of equilibrium between the soil and solvent.

ADSORPTION FROM SOLVENT.

In order to determine the amount of P_2O_5 fixed in the presence of dilute acid solvents, extractions were made in the regular manner using solvents to which known amounts of sodium phosphate were added.

A set of preliminary determinations on soils 1, 2 and 375, using distilled water, N/5 hydrochloric acid, N/5 nitric acid, 1% citric acid and 1% sodium hydroxide, showed the following relation. The fixation from solvent decreased in the order given above. That is, it was highest in distilled water closely followed by hydrochloric and nitric acids. With citric it was considerably less and very low in the presence of 1% sodium hydroxide. Using different concentrations of P_2O_5 in the solvent it was shown that the total amount fixed by the soil increased with increase in P_2O_5 present in the solvent while the percent fixed of that present was greatest at the least concentration. For example in soil 1, N/5 hydrochloric acid being used as a solvent, where .5 gram of P_2O_5 was present, 100 grms. of soil fixed 49%, while where .1 gram was present 100 grams soil fixed 97%.

The results given in Table V show the variation and degree of adsorption in the different soils using 1% sodium hydroxide, N/5 nitric acid and 1% citric acid. On the bottom row of each sub-table are given values in which a correction is made for adsorbed P_2O_5 . While this cannot be considered absolutely accurate, it more nearly approaches the true P_2O_5 solubility. In these experiments 100 grams of soil samples were weighed in duplicate and the solvents added to each, one of which aliquot contained known amounts of sodium phosphate in solution.

TABLE V.
SHOWING FIXATION FROM DILUTE SOLVENTS.

1% NaOH.

Soil No.	375	378	405	1	3	364	398	2
Gms. P_2O_5 added per liter	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700	0.0700
Gms. found per liter..	0.0352	0.0360	0.0516	0.0360	0.0700	0.0296	0.0224	0.0610
Gms. fixed per 100 gms. soil	0.0348	0.0340	0.0184	0.0340	.....	0.0404	0.0476	0.0090
% fixed	50	49	26	48	..	58	68	13
% P_2O_5 in soil sol. in 1% NaOH	0.125	0.176	0.136	0.117	0.566	0.066	0.118	0.048
% P_2O_5 in soil after correction for absorption	0.187	0.262	0.171	0.168	0.566	0.104	0.198	0.054

N/5 HNO_3

Gms. P_2O_5 added per liter	0.0715	0.0715	0.0720	0.0720	0.0715	0.0715	0.0720	0.0715
Gms. found per liter..	0.0118	0.0124	0.0118	0.0044	0.0356	0.0232	0.0267	0.0114
Gms. fixed per 100 gms. soil	0.0597	0.0591	0.0602	0.0676	0.0359	0.0483	0.0453	0.0601
% fixed	84	83	84	94	50	67	63	84
% P_2O_5 in soil sol. in N/5 HNO_3	0.00044	0.00058	0.00121	0.00048	0.1628	0.00038	0.00032	0.00043
N/5 HNO_3 sol. after correction	0.00081	0.00106	0.00223	0.00093	0.2442	0.00064	0.00052	0.00079

1% Citric.

Gms. P_2O_5 added per liter	0.08808	0.0659	0.0659	0.0880	0.0659	0.0659	0.0659	0.08808
Gms. found per liter..	0.01898	0.0127	0.0189	0.02274	0.01650	0.0043	0.0081	0.03810
Gms. fixed per 100 gms. soil	0.06910	0.0532	0.0470	0.06534	0.0494	0.0616	0.0578	0.04998
% fixed	78	81	71	74	75	94	88	57
% P_2O_5 in soil sol. in 1% citric	0.0026	0.0034	0.0035	0.0034	0.319	0.0012	0.0009	0.0024
Citric soluble after correction	0.0046	0.0062	0.0060	0.0059	0.559	0.0023	0.0017	0.0037

The corrected values in Table V still show the relative predominance of basic phosphates over the normal calcium, iron and aluminum compounds.

In view of the ready adsorption in the presence of these solvents as shown and the increase in per cent fixed with dilution the tests were further extended, with citric acid on soils 1 and 2, using lower concentrations of P_2O_5 . These results are given in Table VI and indicate a constant fixation at lower dilutions.

TABLE VI.

SHOWING RELATION BETWEEN CONCENTRATION OF P_2O_5 AND DEGREE OF FIXATION.

Soil No.	1	1	1	1	1	1	2	2	2	2	2	
Mg. P ₂ O ₅ added.....	599.7	88.1	40.0	22.0	17.7	8.2	559.7	88.1	40.0	22.0	17.7	8.2
Mg. P ₂ O ₅ found.....	333.6	22.7	7.0	6.3	2.8	1.5	383.5	38.1	12.5	6.1	5.0	2.4
Mg. P ₂ O ₅ fixed in soil..	226.1	65.4	33.0	15.7	14.9	6.7	176.2	50.0	27.5	15.9	12.7	5.8
% P ₂ O ₅ fixed	40.5	74.0	82.5	71.5	84.5	82.0	31.0	57.0	68.5	72.5	72.0	71.0

It is evident from the above that adsorption is notably less in the presence of 1% citric acid than N/5 nitric and hydrochloric acids. This, in part, accounts for the greater net action of the citric acid on Hawaiian soils and is a factor in favor of its use. Other factors must, however, be admitted as its greater solvent action is still apparent after correcting for adsorbed P_2O_5 . The conclusion then is evident that in attempting to interpret the fertilizer needs of our soils from the citrate soluble P_2O_5 , not only the direct or solvent action but also the reverse or adsorptive action must be considered. It does not, therefore, seem possible to establish an absolute figure to cover all the island types. Adsorption in Hawaiian soils is both high and variable. The restriction of root range and development with our variations in soil type is an important factor in the subsistence of the cane on lesser or greater amounts of available P_2O_5 . These and other factors admit of variations not disclosed in the chemical analysis and not anticipated by the examination of a laboratory sample.

Let us see how this physical adsorption applies in practise. In soils 1 and 2 we have, 1 showing .0032% citrate soluble P_2O_5 , on the unfertilized plots, and giving no response to P_2O_5 ; 2 showing .0022% citrate soluble P_2O_5 , on the unfertilized plots, and giving a distinct response. To adjacent plots in soil 1, reverted phosphate was applied at the rate of 75 lbs. P_2O_5 per acre. To adjacent plots on 2, 90 lbs. P_2O_5 (from reverted phosphate) were applied with an additional comparison on other adjacent plots using 90 lbs. P_2O_5 from acid phosphate. Determinations of citrate soluble P_2O_5 in these soils before and two months after fertilization gave the following interesting results. The P_2O_5 soluble in 1% citric increased in soil 1 from .0044% to .0045%. While in soil 2 it increased from .0040% to .0065% on the reverted phosphate plots and from .0033% to .0096% on the acid phosphate plots. The conclusion from these results appears inevitable that the higher adsorption by soil 1 as shown in Tables V and VI is the principal factor involved. These data further suggest that the citrate value .0022 for soil 2 more nearly represents the true citrate soluble P_2O_5 than the value .0032 for soil 1 and illustrates the "pitfalls" these variations introduce.

NATURE OF THE ADSORPTION.

Scientists at the Bureau of Soils,²¹ U. S. Department of Agriculture, have recently separated, from clay soils, large quantities of soil colloids. They have noted the effect of heat and alcohol on their adsorptive powers.

It may be of interest to submit, at this point, data covering the effect of heat and alcohol on the adsorption of P_2O_5 by our soils from citric acid solution. These results merely emphasize the role of physical adsorption by the colloids in Hawaiian soils and its relation to citrate soluble P_2O_5 .

One hundred gram samples of soils 1 and 2 were heated at dull redness, in a muffle, for one hour, thus destroying both the colloids and hydrates. These samples were then extracted with citric acid in the regular manner.

The results of these analyses are given in Table VII:

TABLE VII.

SHOWING EFFECT OF DESTROYING COLLOIDS AND HYDRATES ON SOLVENT ACTION OF CITRIC ACID.

	P_2O_5	SiO_2	Fe_2O_3	Al_2O_3	Mn_2O_4	CaO	Gms. Acidity Neutralized of 1 Gm. Added
Soil No. 1—Air dry	0.0032	0.180	0.055	0.132	0.237	0.164	0.20
Soil No. 1—Heated dull red	0.0670	0.852	1.88	0.853	0.130	0.210	0.45
Soil No. 2—Air dry	0.0022	0.090	0.142	0.434	1.212	0.192	0.74
Soil No. 2—Heated dull red	0.0678	0.746	1.53	0.942	0.83	0.260	0.59

These data clearly show the predominating influence of physical factors in the adsorption of P_2O_5 from 1% citric acid when this acid is used as a solvent. The acidity neutralized during extraction and the increased solution of bases in the heated soil indicate the minor role of chemical factors. For example, precipitation as insoluble salts in the presence of the solvent. It is of interest to note the greater solution of iron, alumina, and P_2O_5 in the heated samples proving the presence of the hydrated phosphates of these elements and their conversion to more soluble form by destroying the hydrate.

In view of this role of the colloids in inhibiting the complete solution of citrate soluble P_2O_5 , what effect would the presence of substances, in the citric acid solution, which in themselves would lower the adsorptive power of the colloids, have on the adsorption of P_2O_5 by the soil from 1% citric acid? Theoretically the presence of alcohol in the citric acid should lower this adsorption. With this in mind 1% citric acid in solution of varying amounts of water and ethyl alcohol was used as a solvent on soil 1 with the results given in Table VIII.

TABLE VIII.

SHOWING FIXATION OF P_2O_5 FROM 1% CITRIC ACID IN PRESENCE OF ALCOHOL.

Per cent alcohol	50	25	10	5	0
P_2O_5 mgm. added	187.5	160.5	147.2	65.4	88.0
P_2O_5 mgm. found	63.4	106.7	113.2	23.0	22.7
P_2O_5 mgm. fixed	124.1	53.8	34.0	42.4	65.3
% P_2O_5 fixed	66	33	23	65	74
% citrate sol. in soil	0.0007	0.0010	0.0010	0.00075	0.0032

The higher apparent adsorption with 50% and 25% alcoholic citric acid is probably due to the low solubility of phosphate in alcohol, in other words, precipitation. It will be noted that in the presence of 10% alcohol the adsorption is at a minimum and that while the tendency is in the "right direction" the practical elimination of fixation in analysis does not appear probable. The figures given in the bottom row in Table VIII show that while fixation is lowered in the presence of alcohol the solvent action of the citric acid is inhibited.

MORE COMPLETE COMPOSITION OF SOIL EXTRACTS.

In order to further add to our knowledge of the action of these dilute solvents on our soils analysis of the extracts was extended to include silica, iron, alumina, manganese, lime and magnesia. The results are given in the following table:

TABLE IX.
SHOWING RELATIVE COMPOSITION OF DILUTE SOLVENT EXTRACTS.
1% Citric Acid.

Soil No.	Soil Color.	Gms. Acidity Neutralized.	P ₂ O ₅ .	SiO ₂ .	Fe ₂ O ₃ .	Al ₂ O ₃ .	Mn ₃ O ₄ .	CaO.	MgO.	H ₂ O.	
375	Dark brown141	.0024	.145	.208	.195	.833	.319	.091	4.58	No response
378	Dark brown .....	.180	.0032	.095	.159	.290	1.064	.257	.088	4.67
405	Red .....	.676	.0033	.105	.239	.213	.599	.207	.050	4.79
1	Brown .....	.20	.0030	.180	.055	.132	.237	.164	...	6.00
3	Greyish black .....	.585	.297	1.236	.626	.683	.066	1.116	.229	7.00
364	Yellowish brown572	.0012	.016	.131	.134	.013	.050	.011	7.31	Response
398	Yellow .....	.480	.0009	.019	.152	.092	.005	.048	.011	5.02
2	Dark red .....	.736	.0020	.090	.142	.434	1.212	.192	...	8.00

N/5 HNO₃

375	Dark brown233	.00077	.134	.038	.465	.365	.341	Not determined	4.58	No response
378	Dark brown .....	.202	.00100	.117	.032	.625	.248	.308		4.67
405	Red .....	.151	.00200	.120	.038	.942	.026	.311		4.79
1	Brown .....	.126	.00087	.239	.058	.286	.046	.237		6.00
3	Greyish black .....	.466	.22710	.633	.090	1.151	.099	.313		7.00
364	Yellowish brown089	.00058	.012	.052	.317	.020	.059	Not determined	7.31	Response
398	Yellow .....	.082	.00049	.008	.126	.287	.250	.065		5.02
2	Dark red .....	.138	.00074	.199	.056	.66±	.222	.270		8.00

1% Sodium Hydroxide.

375	Dark brown178	.190	.12	1.291	None	Trace	...	4.58	No response
378	Dark brown .....	...	.250	.164	.09	1.092			...	4.67
405	Red .....	...	.163	.570	.09	1.121			...	4.79
1	Brown .....	...	.165	.724	.07	1.540			...	6.00
3	Greyish black .....	...	.526	.350	.06	.824			...	7.00
364	Yellowish brown096	.056	.54	.979	None	Trace	...	7.31	Response
398	Yellow .....	...	.188	.100	.24	1.068			...	5.02
2	Dark red .....	...	.050	.524	.16	.646			...	8.00

The value of 1% sodium hydroxide as a solvent for iron and aluminum phosphates is clearly indicated by the absence of lime in solution. Also that of N/5 nitric acid for the calcium phosphates by the larger amounts of this element in proportion to iron and aluminum soluble in this solvent. While the analyses do not absolutely prove such to be the case, they, however, strongly indicate the presence of aluminum phosphate in excess of either that of iron or calcium. The low solubility of iron as compared to aluminum in N/5 nitric acid is especially noted. On the other hand the greater solvent action of 1% citric acid upon iron and the lesser solvent action on alumina and lime indicate that the higher P_2O_5 figure obtained with citric acid may be due in part to a greater solution of iron phosphate than when N/5 nitric acid is used.

While calcium phosphate is more soluble in the soil solution than either iron or aluminum phosphates their availability is closely related. Pot experiments¹² on Hawaiian soils have shown the distinct response obtained on adding normal iron and aluminum phosphates to Hawaiian soils to be practically equal to that obtained on using acid phosphate. It is therefore evident that the higher figure obtained with 1% citric acid represents the phosphate compounds most available.

In comparing the composition of the extracts from those soils giving no response to P_2O_5 and those giving a response, the wide variation in iron, aluminum and manganese is noted. There is no apparent relation between these elements and the availability of P_2O_5 . It is, however, significant that basic iron phosphate is higher in those soils giving no response.

On the other hand in silica, lime and magnesia we note a relationship of no small importance. The only variation in relative silica, lime, magnesia to available P_2O_5 is that of soil 2, a highly manganiferous type, which type usually shows a high solubility of basic constituents in dilute solvents.

It has generally been assumed that the presence of lime aids in the reversal of soluble phosphates, such as acid phosphate, to the less soluble calcium salt in the soil. That it functions as such in Hawaiian soils is probably true but still open to question. Pot experiments¹² on our red ferruginous clays have shown indications of its functioning to a limited extent as such. Furthermore, the sandy type of soil in and about Honolulu (Station soil), which may be classified as a highly calcareous type, is very high in calcium phosphate content and does not respond to phosphate fertilization. In view of the analytical results given in Table IX it is evident that the presence of more soluble forms of lime is a factor in the availability. For further information let us refer to Bul. 45, A & C series this Station, and note the results obtained in the Survey of (Island) Hawaii Soils. In the Hilo-Hamakua district, citrate soluble lime is low (soils very acid). Citrate soluble P_2O_5 is also low in spite of high total P_2O_5 . In the Kau district the citrate soluble P_2O_5 is the highest on the island, likewise lime is high and soils of low acidity or alkaline. Similar relations exist in the Kohala district except that the lime content is not so high as in Kau, while in the Hilo-Puna district we note also a high citrate soluble P_2O_5 with fairly high lime.

Wheeler²³ found iron and aluminum phosphates, with lime, to be better than acid phosphate, basic slag and floats. Similar results have been obtained in Australia.²⁴ Whitson²⁵ and Stoddart¹⁷ found a low comparative P_2O_5 con-

tent in acid soils. The data submitted in Bul. 45 indicate low available P_2O_5 to be associated with soil acidity and warrants further study.

While the literature covering the relation of silica or silicates to the availability or assimilation of P_2O_5 is limited, Hall and Morrison²⁶ have published a very comprehensive report of investigations along this line at Rothamsted, where sodium silicate has been applied as a manure on experimental plots over long periods of time, and shows well marked results. It was noted thereon that barley grown on those plots to which silica was added closely resembled that on the phosphate plots, especially at the ripening off stage. This then led to a study of the relation between the function of phosphates and silica with the following conclusions: Although silica cannot replace P_2O_5 , or even economize and make more effective a restricted supply already within the plant, it will stimulate the plant to assimilate a greater amount of P_2O_5 should that be obtainable from the medium in which the plant is growing. Hence, when applied to a silica plant, and sugar cane may be rightly placed in this class, on a soil impoverished in P_2O_5 it has the same effect as a direct application of P_2O_5 . They also showed by experiment that silica has little or no effect on the solubility of P_2O_5 in citric acid except on those plots receiving P_2O_5 as a manure. From which they claim that soluble silica in the soil has no action on soil P_2O_5 .

With the limited information available in Table IX, it is impracticable to comment upon the local application of the above contentions of Hall and Morrison. It is hoped, however, that a further study of this problem will throw some light upon it. The higher silica content soluble in N/5 nitric, 1% citric and 1% sodium hydroxide, uniformly accompanies no response to P_2O_5 in all the soils investigated. The relation of soluble silicates to the availability of P_2O_5 to sugar cane in our Island soils can only be determined by culture experiments.

SUMMARY.

Burgess²² has given the comparative P_2O_5 content (strong hydrochloric acid digestion) of Hawaiian and mainland soils as .35% and .16%, respectively. In view of the higher percent of total dissolved from mainland soils the variation in total P_2O_5 is probably higher than this figure. While on mainland soils .30% is considered a very high P_2O_5 content, and soils containing as low as .05 to .10% often give no response to phosphate fertilization, in attempting to make recommendations from comparative analyses reservation has always been made for any high iron and alumina content. The wide variation in P_2O_5 dissolved from mainland soils by strong acids is due principally to their high silica content, as silicon dioxide, which under certain conditions protects a varying amount of P_2O_5 from the solvent action of the acid. In Hawaiian soils, silica is present, in major part, as silicates, more easily broken down in acid digestion. This with other factors brought out in this investigation indicates the insoluble P_2O_5 to be present as highly insoluble compounds. On this basis the relation of the total P_2O_5 in Hawaiian soils to that soluble in strong acids, gives a certain amount of indication of its solubility. Without the total P_2O_5 content for comparison these results are of little value except where a deficiency is apparent.

The principal phosphate compounds present are the basic (hydrated) phos-

phates of aluminum and iron. Results indicate the former to be in excess. Lesser amounts of normal phosphates of aluminum, iron, calcium, and possibly magnesium are present. In these more soluble forms as measured by dilute acids, aluminum again appears to be in excess of iron with the calcium phosphate least.

We have, in dilute citric, nitric, and hydrochloric acids empirical solvents for the normal phosphates of iron, aluminum and calcium. The strength of solvent is more or less arbitrary. Within certain limits the strength and method of extraction once chosen, however, should be maintained. Extensive investigations covering the use of these solvents has resulted in the empirical adoption of 1% citric, N/5 nitric, and N/5 hydrochloric as the most desirable solvents. We note in literature some investigators favoring the use of one or both of the mineral acids while others favor the use of citric as showing a more comprehensive relation to field tests.

The choice of a weak solvent depends more or less upon such factors as adsorption, soil colloids, nature of the soil bases, etc. For Hawaiian soils 1% citric acid as a solvent is influenced less by the adsorptive action of the soil colloids and exercises a greater solvent action than the mineral acids of N/5 strength. Also, it is not necessary to allow for the citric acid neutralized during the extraction and in addition successive extractions indicate a more or less constant value after one extraction. That is, the P_2O_5 dissolved after one extraction is so small as to be negligible.

Is it then practicable to establish a working agreement between the citrate soluble P_2O_5 in Hawaiian soils and their fertilizer needs, as applied to areas devoted to sugar cane culture? To say that such is possible over such extended areas as the mainland of the United States, or even one state, the soils of which are planted to diversified crops, is admittedly absurd. We are concerned in our case with only one crop, sugar cane, which is admittedly not a heavy "phosphate feeder." Maxwell,²⁷ in a study of thirteen varieties of cane grown on the same soil, under control conditions and carefully analyzed, found that the P_2O_5 removed from the soil varied from 170 to 290 lbs. per acre.* These results indicate either a variation in the phosphate needs or the feeding power of these varieties. The lands devoted to sugar cane culture embody only the lower elevations, involving thereby less variation in soil type. The extent of this variation has not been definitely determined. The two essential factors, then, that stand out are a knowledge of the feeding power or P_2O_5 needs of the standard cane varieties of the Islands and a more systematic classification of the soil types devoted to sugar cane culture.

One per cent citric acid has been most extensively used at the Rothamsted Station in England, where Dyer¹⁸ established .01% (citrate soluble P_2O_5) as the limit below which a phosphate need was indicated. Hall and Plymen¹⁹ on applying this to experiment plots at this same station obtained a response to P_2O_5 fertilization on four plots showing .0087, .01, .013 and .021%. On a fifth they obtained no response when .0082% citrate soluble P_2O_5 was shown.** Hall,

* These amounts appear high, due possibly to the cane having been grown at Makiki plots, where soil is extremely rich in phosphoric acid. The figures are introduced to illustrate existing variation.

** Total P_2O_5 on these soils approx. 0.1%.

nevertheless, admitted a working agreement of considerable value, suggesting .02% as a minimum instead of the .01% of Dyer. It is interesting to compare the high total P_2O_5 content of Hawaiian soils and the low citrate figure, .004%, which general observations have indicated as the approximate minimum for our soils.

In the laboratory we find that due consideration must be allowed for the reverse or adsorptive action as well as the solvent action of 1% citric acid during the course of the analysis. Also that there appears to be a relation between the calcium and soluble silicate and the assimilation of P_2O_5 . These and other factors entering into the chemical examination of the soil with 1% citric acid do not allow of a thoroughly sound scientific basis on which to establish the relation between the P_2O_5 dissolved by this solvent and the P_2O_5 needs of the soil. Yet it does not preclude the possibility of a practical working agreement between the P_2O_5 needs of known varieties of cane on similar soil types when backed up by field observations.

The chemical examination of a laboratory soil sample, regardless of the nature of this examination, is more or less empirical in spite of the soundness of its scientific basis. Variation in soil type and plants to be cropped thereon must need be considered. We know, for example, that plants thrive on less available phosphate in a sandy soil than in a clay, due to their greater root range in the former.

All facts considered, the reduction of probabilities to a minimum must involve a knowledge where possible of the previous performances of the field in question; otherwise the overindulgence in probabilities is inevitable where chemical analysis only is at hand on which to base recommendations. The proper balance between fertilizer, crop and soil which is essential to optimum growing conditions cannot be determined through a knowledge of one factor alone.

FOOTNOTES.

1. H. S. P. A. Exp. Sta. Record XXIII, p. 212.
2. H. S. P. A. Exp. Sta. Record XXI, p. 84.
3. H. S. P. A. Exp. Sta. Record XX, p. 333.
4. H. S. P. A. Exp. Sta. Record XXV, p. 20.
5. H. S. P. A. Exp. Sta. Record XXIV, p. 58.
6. U. S. Geological Survey Bul. 700.
7. Md. Exp. Sta. Bul. 70.
8. Va. Exp. Sta. Bul. 200.
9. Jour. Ind. Eng. Chem. V, p. 664.
10. Wisc. Exp. Sta. Res. Bul. 2.
11. Jour. Am. Chem. Soc. XXVIII, p. 823.
12. Haw. Agric. Exp. Sta. Bul. 41.
13. Jour. Ind. Eng. Chem. II, p. 277.
14. Ky. Exp. Sta. Bul. 126.
15. Minn. Exp. Sta. Bul. 102.
16. Texas Exp. Sta. Bul. 126.
17. Jour. Ind. Eng. Chem. I, p. 69.
18. Jour. Chem. Soc. LXV, p. 115.
19. Jour. Chem. Soc. LXXXI, p. 117.
20. Jour. Chem. Soc. LXXXIX, p. 205.
21. Jour. Ind. Eng. Chem. XIII, p. 527.

22. H. S. P. A. Exp. Sta. A & C Bul. 45.
23. Jour. Ind. Eng. Chem. II, p. 133.
24. Exp. Sta. Record XL, p. 24.
25. Jour. Am. Chem. Soc. XXIX, p. 757.
26. Proc. of Royal Society B. LXXVII, p. 455.
27. H. S. P. A. Exp. Sta. A & C Buls. 5 and 6.

Collapsed Boiler Tubes.*

An instance of the peculiarities attending boiler accidents came to the author's attention last year when he had occasion to make an internal inspection of a horizontal return tubular boiler, which was found showing evidence that the water in the boiler had at some time been allowed to reach a low level. Generally speaking, to allow the water in a steam boiler to fall below a predetermined safe working level causes the exposed tube ends and seams to leak, and it is not unusual to find it possible to have the boiler placed again in a serviceable condition by expanding the tube ends and caulking the seams to make them tight.

The boiler mentioned in this article was supplied with feed water by direct connection with the pressure main. The operator had various duties to perform, requiring periodic absence from the steam plant, and due to the practically unvarying load on the boiler, found it possible to adjust the feed water valve and the oil burner to maintain a fairly constant water level and steam pressure. During a temporary absence of the operator, the water in the main was shut off without previous warning, due to necessary repair to the water supply system, and when the attendant returned to the boiler he found no water in sight in the gauge glass, and a test of the feed connection showed no water pressure in the supply pipe.

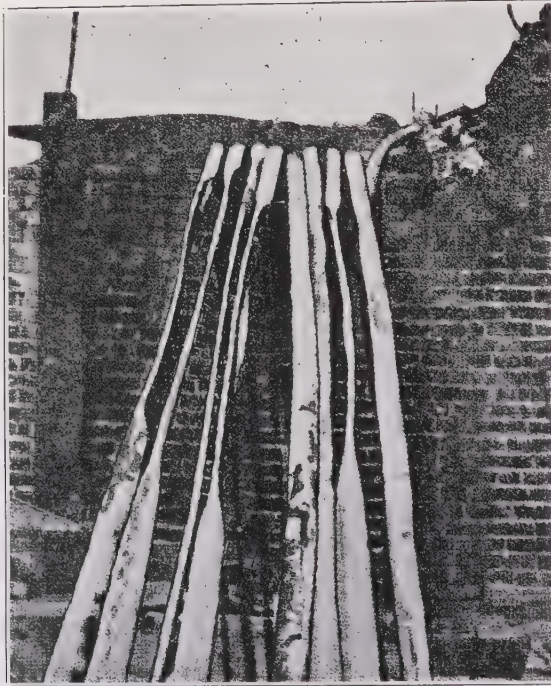
The boiler was shut down and it was found that the water had fallen to a point about 18 inches above the bottom of the shell. A great many of the tubes were therefore found not covered with water and, of course, leaked considerably, the rear head seam also requiring to be caulked tight. Up to this point the proceeding is what may be termed "regular," but when 17 of the tubes were found collapsed, some partially and others totally, a condition arose that was "irregular," as it is not common to find tubes collapsed in cases of low water.

The collapse in this instance appears to be attributable to the fact that considerable soot had collected in some of the tubes and caught fire, causing overheating of the metal and reducing its power of resistance to a point where collapse was possible. Many of the tubes were badly buckled, 40 requiring renewal. These, together with the 17 that collapsed, represent a repair cost of considerable size, the tubes being 3 inches in diameter and 16 feet long. The

* From Power Plant Engineering.

accompanying photograph will prove interesting in showing the extent of collapse and to what degree some of the tubes were buckled.

In many accidents there are revealed ways and means by which their prevention would be effected, and in this case, if the feed water had been supplied by a pump in conjunction with a storage tank, it is quite possible that the condition brought about would not have occurred.



Collapsed and buckled tubes resulting from low water.

Prolonged absence of an operator from an active boiler is to be looked on with much disfavor, not being conducive to its safe operation and contrary to the principle of "Safety First." In some states and municipalities the length of time which a boiler may be left without an attendant is fixed by statutes and ordinances, as it is recognized that a boiler under steam pressure represents a potential hazard.

[W. E. S.]

The Origin of New Canes by Bud Variation.

By C. A. BARBER.

This is another article pertaining to the general subject of improving sugar cane through selection. It was published originally in the Agricultural Journal

of India and was reprinted by the *International Sugar Journal* in 1907. All of this early work is important for the bearing that it has upon the project of bud selection in its present stage of development. Observations covering color variations in cane go back to the days of Charles Darwin.

Other papers of this character will be published from time to time in an attempt to make a review of this work up to the present time, when it attains much commercial significance when reduced to the working basis of selecting cane stools based upon their size, uniformity, and number of sticks.

One of the most striking facts connected with sugar cane cultivation is the enormous number of varieties which, though easily separable, have the greatest botanical similarity. It is frequently possible to distinguish two varieties without being able to put down clearly wherein the difference between them exists. The difference may be in the form of the joint, in the tinge of color, in the habit of the plant in the field, in its thickness or height, in the richness of the juice expressed. Again, with no external differences at all, there may be such a difference in constitution that, whereas one cane grows clean and healthy and yields a certain crop, the other is swept out of the fields by disease.

Even after prolonged study it is difficult to decide how all these varieties have arisen. There is no doubt as to the ancient character of sugar cane cultivation. While it is probable that the cane was first cultivated in a certain Asiatic region, yet nowhere can we lay our hands on a *Saccharum*, now wild, which presents any probability of being the progenitor of the cultivated forms. The matter is not rendered easier by observing how peculiarly susceptible the sugar cane is to any change in its environment. We cannot tell beforehand in what direction changes are likely to occur, but certain it is that if two canes are taken from one part of the country to another, their characters under the new condition differ, whether in color, form, or sugar-making properties. The pet cane of one region quickly assumes a very second rate character in another, being left behind by a cane which could in no way be considered its rival in the land of its origin. Some improve in their juice and others deteriorate, some change their color and others do not, while some really good canes dwindle to the size of the local "reeds" which are everywhere to be found where sugar cane has long been cultivated.

With these obvious facts before us, there is an entire absence of a good connected series of observations, and we have to confess that we know next to nothing as to the way in which the countless varieties of sugar cane at the present day have arisen.

From this point of view a study of the striped canes, or those which have two main colors alternating in their stems, appears most likely to lead to interesting results. And the first subject for investigation is to try to find out how these varieties have arisen.

In all likelihood the yellow or green canes were the first obtained and cultivated, and the others arose as subsequent varieties. The assumption of a red color by the rind of plants under cultivation is by no means an uncommon phenomenon. The striped canes would probably be the last formed, and there is

some reason for supposing that each striped cane has for its parents two canes, a red and a yellow one. Such striped canes may have arisen in several ways. Firstly by seminal crossing. While seedling canes appear to be very rare in India, they are not at all uncommon in certain tropical islands; and it is fair to assume that in past times this seminal reproduction was much commoner than it is at present. The practice of growing canes of different varieties in the same field is probably very ancient, and we have a ready means by which the striped canes may have originated. That they have arisen late, among canes already cultivated, appears to be also probable from the fact that the striped canes as a whole are ones of good character from the milling point of view, and while there are numerous yellow and less frequently red canes of a reed-like primitive nature, such canes are hardly ever striped. But there is just sufficient evidence to render it possible that these striped canes have arisen from the apposition of two canes of different colors by natural grafting, and it is possible that some at least of the striped canes are in reality graft-hybrids. The general absence of grafts among monocotyledons renders this less likely but not impossible, and exhaustive experiments are called for to determine whether we may not by this method hope to raise new varieties. But the strongest argument in favor of the origin of striped canes from parents of two different colors is the not infrequent reversion of these varieties into canes of single colors. Such "sports" are by no means infrequent and form the subject of the present paper.

It is a matter of common knowledge among the Godavari ryots that in a field of Namalu (striped red and yellow) canes, sooner or later the number of Keli (yellow) canes increases. And when we take the Namalu and Keli canes and compare them from a botanical and chemical standpoint, it is difficult to find any real difference between them excepting in their color. There is then a strong presumption that the Keli is a natural sport from the Namalu. And it may be at once asserted that the tendency in the striped canes is always to produce yellow rather than red sports, a fact which seems natural when we consider that the yellow canes are probably the older and nearer to the original cane of the primitive cultivation.

The following canes have been noted in the short life of the Samalkota Sugar Station in the Godavari district. The cane known there as the "Striped Mauritius" has been seen frequently to sport into green canes and less often into canes of a pure red. There are now good plots of all these canes, and they have been submitted to analysis for two years. There is no doubt that the three canes have sufficient differences, besides their color, in the richness of their juice and in their habit of growth, to constitute well-marked varieties in the ordinary sense of the term. It is quite in accord with what has been suggested above, that the green is the hardier, bunches more readily, and has inferior juice; that the red cane, on the other hand, is little inferior, if indeed it is not superior, to the striped, which otherwise holds an intermediate position between the other two.

The thick striped cane, called on the farm the "Dark Striped Mauritius," has also been identified as the parent of the yellow "Ivory Mauritius," but no red cane has yet been obtained from it. The long striped cane obtained from various parts of South India, called by some the "Striped Singapore," has sported into both red and yellow, but the characters of these have not yet been deter-

mined. Finally, the striped cane growing in Abraham Paudither's garden at Tanjore (which cane may be identical with the last named) has given rise to a new ashy cane which appears to be well worth cultivating.

This mode of origin of new cane varieties has been termed "Bud-variation." After observing the facts described above on the farm at Samalkota three years ago, my attention was drawn to an article in the West Indian Agricultural Bulletin, where the subject was exhaustively dealt with. No analyses were, however, published of the different canes arising from bud-variation. As in the cases noted above, it was always a striped cane which showed this phenomenon in the West Indies, Louisiana, and Mauritius. It is worthy of note that this bud-variation does not consist in certain buds growing out to form new canes of one color, but isolated buds show variability and give rise to shoots of different colors, sometimes, indeed, to a shoot whose base is striped, but which becomes yellow in its upper part. The idea that a bud in the red part of a striped cane gives rise to a red cane, whereas one in the yellow part produces a yellow, is apparently not correct. The canes thus arising appear to retain their characters, and have remained constant for three or four years already.

Now this fact, that the striped canes have alone been observed to "sport," may be explained in two ways. On the one hand they may be true hybrids which have arisen from the crossing of the two one-colored canes, and consequently may have a greater tendency to vary than the one-colored canes. But on the other hand the frequency of the phenomenon in striped canes may be due to the fact that, while such changes in color are very readily seen in them, they would require very careful observation in the case of ordinary canes. And I think that the latter is more likely to be the explanation. If such is the case, it behooves us to study our fields with much greater care than heretofore. Whenever, in a uniform field, canes appear which show any marked differences from the rest, they should be carefully segregated, cultivated, and analyzed. A certain amount of work has been done in this direction at Samalkota, but the results thus far obtained have not been satisfactory. Chance differences which have been observed have not been maintained. But this is no reason why the subject should be dropped, and observations will be continued as opportunity offers.

With reference to the Striped Mauritius and its "Sports," the more important figures in the two years' analyses have been reproduced in the table. The Green Sports may be classed as a cane distinctly inferior to the other two, whereas the Ivory appears to be distinctly better than the Dark Striped. The Red Sports during the first year showed such good results that it was thought that a new cane of great value had been discovered. It was accordingly named the "Gillman," after the Collector of Vizianagram, through whose energy and forethought these Mauritius canes had been introduced into Madras. These canes and others obtained in the future will be multiplied, and, in due course, valued and added to those on the farm, or rejected, according as they turn out.

ANALYSIS OF STRIPED CANES AND SPORTS IN THE GOVERNMENT SUGAR
CANE FARM, SAMALKOTA.

Varieties		Juice				Bagasse: Per Cent Obtained by Crushing
		Corr. Brix	Per Cent Sucrose	C. P.	Per Cent Glucose	
Striped Mauritius,	1904-05..	20.44	19.33	94.57	0.30	37.23
“ “	1905-06..	21.31	19.94	93.57	0.67	37.53
Green Sports,	1904-05..	20.29	18.66	91.96	0.60	33.92
“ “	1905-06..	18.57	16.61	99.45	0.93	34.79
Red Sports,	1904-05..	21.35	20.23	94.75	0.30	39.67
“ “	1905-06..	20.16	18.88	93.65	0.67	34.48
Dark Striped Mauritius,	1904-05..	17.06	13.98	81.94	1.54	36.87
“ “ “	1905-06..	16.98	13.95	82.15	1.95	36.86
Ivory Mauritius,	1904-05..	18.67	16.11	86.29	0.75	38.96
“ “	1905-06..	17.87	15.37	86.01	1.34	40.41

The Sugar Industry in Java.*

As seen by the Indian Sugar Committee.

It is a curious fact that, although masses of detail are published every year about the Java sugar industry, there are few countries about which more contradictory statements are served up by journals dealing with sugar matters. And these statements refer to the most varying factors, such as the relative fertility of the soil, the relations between the planters, the Government and the land-owners, and even the production of sugar in any one year. It may be that this confusion is partly due to the presentation of the information in the Dutch language, which has its own peculiar difficulties to the English or American reader; but, whatever the cause may be, any first-hand description of the industry of an authoritative nature is likely to be welcome. We have therefore thought it worth while to place before our readers a summary of some of the points in the second chapter of the Report of the Indian Sugar Committee, which contains a careful account of their observations during a month's stay in the island. As the Dutch Government and the planting community appear to have given them every facility for forming just views as to the state of affairs in the sugar industry, we may with some show of reason regard this account as more or less of an authoritative nature.

It may be well at the outset to explain that the sugar factory and plantation in Java are under one head, and that the mill and the cane fields work in complete accord. Further, whatever may have been the case in the past, the sugar

* The International Sugar Journal, September, 1921.

industry is entirely self-contained as regards all investigations for the improvement of cultivation and manufacture. The entire cost of all the complicated machinery for carrying out these investigations is borne by the industry, by means of voluntary cesses on acreage of cane, amounting at the time when the report was written to about 6s. per acre planted; and the expenditure for research alone during 1919-20 reached the sum of 1,200,000 guilders or £105,000. No help was obtained from Government, whose experimental stations are mainly, if not entirely, concerned with crops other than sugar cane.

It is generally recognized that the success of the Java sugar industry during recent years has been mainly due to the intricate organization for the solution of the many difficulties which occur in all cane-growing countries, and of which Java has had its full share. This organization will accordingly be dealt with in this note in some detail, especially as it is entirely built up by an industry as contrasted with a Government, with all the attendant directness of view and practical nature. And it is none the less surprising that nowhere in the sugar world is a higher value placed on the work of pure as well as applied science. This we have, during a long experience, come to regard as a characteristic feature of the Dutch, namely, a great appreciation of the value of modern scientific work, coupled with a peculiar capacity for the practical application of the results obtained.

For the administration of the affairs of the industry as a whole, at any rate those factories which have agreed to pay the cesses, two main bodies have been called into existence, a General Syndicate of Sugar Manufacturers and a Research Station Association. The GENERAL SYNDICATE, with headquarters at Soerabaia, is maintained by a cess of 1.25 guilders per bouw (the guilder = 1s. 8d., and the bouw = $1\frac{3}{4}$ acres), up to a limit of 1750 bouws under one control. Its sphere of action is of an economic and political nature, and its forms a channel through which its members can make their influence felt by the Government, as to the relations between factories and land-owners, the levying of export duties, and matters of similar nature. The functions of the Syndicate are divided between three separate bodies, the General Assembly of Members, a Council, and a Board. The Assembly usually meets twice a year (although special meetings may be called), and its main work is the fixing of the annual contribution by the members, passing the accounts, and sanctioning the budget. The Council is a purely advisory body, but from the nature of its constitution (mentioned below) it has great influence with the Board, which is the main executive body. The Board usually meets once a month, under a president who has large powers for the transaction of ordinary business between the meetings, and is assisted by a permanent paid staff. Half of the members of the Board are nominated by the Council and the other half selected by the Assembly, which also appoints the president. For keeping in touch with all the factories which are members of the Syndicate, the island is divided into 16 sections, which more or less correspond with the Government administrative divisions, and each of these sections has a local Board, whose chairman is always the manager of a factory within its limits. It is the 16 chairmen of these local Boards who form the Council of the Syndicate, as well as the Council of the Research Association

to be referred to later. Thus, all parts of the industry are fully represented in the management of affairs.

The RESEARCH ASSOCIATION, which appears to have a similar constitution to the General Syndicate, deals with agricultural and manufacturing matters, and has, as is natural, a more complicated network of sub-divisions. Under the executive Board there are three independent departments: Agricultural, with headquarters at Pasoeroean, and Chemical and Engineering at Semarang. It will be necessary briefly to consider the work of each of these. The funds of the Association are derived from a cess of $4\frac{1}{2}$ guilders per buow under cane, with an additional half guilder where a "group adviser" is employed (as detailed below), making a total of 5 guilders per buow, up to the limit of 1750 buows under one factory as before.

THE AGRICULTURAL DEPARTMENT. To the buildings at Pasoeroean a farm of 25 bouws is attached, for the use of workers in the various sections, with the novel condition that the land is rented season by season, just as is the case with factory lands. There is also a sub-station at Cheribon, in West Java. There are a director, assistant director, and secretary, and scientific heads of the following sections: Physiology, agro-geology (including the chemical analysis of soils), cane-breeding, bacteriology, statistics, and field experiments. Formerly there were also entomological and mycological officers, but these have been abolished as no longer needed, because of the successful control of pests and diseases by efficient cultivation. Broadly speaking, the work of the departments is concentrated on seeing that the right kind of cane is grown on the right soil, the evolution of hardy and heavy yielding varieties of cane, and the elimination of disease by proper control. The most important investigation at present being carried out is on varieties, but much is also being done on the testing of seed from different sources (e.g., hill and plains nurseries), reduction of sets per acre, depth of planting, width of rows, possibility of replacing sulphate of ammonia by some other manure, the amount of nitrogen needed per bouw for every field, the necessity or otherwise of phosphatic manures, the best time of applying manures, the use of waste products, etc. In order to keep the work at Pasoeroean available for the plantations, a special set of touring officers is attached to the section of field experiments. There are at present about 11 of these, and each has from 10 to 20 factories in his circle. They communicate the Pasoeroean results to the managers, and are consulted by them as to varieties, diseases, etc., and are therefore termed "group advisers." They collect information for the heads of sections, make soil surveys and a soil map of all plantations employing them, and conduct on the average one experiment each year on every estate which is willing to bear the cost. This is usually readily conceded, as the experiments are almost invariably financially profitable.

The CHEMICAL and ENGINEERING DEPARTMENTS are stationed at Semarang, and are under a joint head who is a vice-president of the Research Association. Each has its own director and secretary. The Chemical Department has two sections, one of which deals with purely scientific matter, analyses, etc., while the other deals with technical research and chemical control in factories. The Engineering Department has also two sections, the first having four sub-sections, namely, consulting, technical research, mill control, and office, while

the second is purely electrical. The heads of these sections and sub-sections are recruited from the Technical School at Delft. Among the subjects at present being worked out are briquetting of bagasse, behavior of bagasse under pressure, the best methods of taking samples for mill work, the best methods of driving mills by electricity, and so on. The two departments publish fortnightly figures of the working of the factories on the chemical and engineering sides, and prepare a complete synopsis of the season's results. As the officers constantly visit the factories, there are no group advisers.

RELATION BETWEEN THE FACTORIES AND THE LAND-OWNERS. The arrangements are a survival of the culture system of Governor Van Der Bosch a century ago, all compulsion having long ceased; and the success of the industry is largely dependent on the agricultural control of the land by the factories during the term of their lease. No non-native can acquire land in Java from a native, and the longest lease is therefore fixed at $21\frac{1}{2}$ years, although it is usually much shorter, namely, for the time required to grow one crop of canes, roughly a year and a half. Rent is fixed at a figure supposed to equal the profit which could be obtained from one crop of rice and two dry crops, which could be raised in the time, and is subject to revision every five years. The minimum rent as fixed by Government is now about 60 guilders per bouw per annum, or 90 guilders for the season; besides this, from 2 to $7\frac{1}{2}$ guilders are paid for returning the land to its normal condition for a rice crop. Competition between factories for the land is impossible, for they have to be licensed by Government and are not allowed to interfere with one another or with the food growing needs of the people. For safeguarding the latter not more than one-third of the land in any village may be leased. New licenses are now very rare and the number of factories in Java has for some time been practically stationary.

CULTIVATION. The most interesting of the methods employed by Java is that of procuring sets for planting. These are obtained from three sources: hill nurseries (1000-3000 ft.), plains nurseries and tops of the crop cut on the plantations; and owing to the great cost of the first, the tendency is to increase the second source, the nurseries either being off the estate but at a lower level, or even on the estate itself. In both kinds of nurseries no cane is harvested, but the plants are cut up after six months' growth, producing two to three sets each stalk. In the plains nurseries another method is also employed, only the top being cut off and the remainder being left to grow for a further 10-45 days, after which the whole is cut up: each set then has one or two young shoots whose leaves are trimmed to prevent evaporation. These shooting sets are termed "*rajoengans*" and are used for middle and later sowings. They are only produced on factory lands, as they cannot be transported far. Some sets are always obtained each year from the hill nurseries, the average for most of Java in 1918 being 35 per cent hills; 31 per cent plains; 34 per cent tops; while in Djokjakarta, where the climate is favorable, the figures were 4 per cent, 66 per cent, and 30 per cent, respectively. The quantity of hill sets required for one bouw in 1919 was $3\frac{1}{2}$ - $4\frac{1}{2}$ tons, costing 93 guilders per bouw (66s. per acre), against 40 guilders per acre (30s. 8d. per acre) for plain sets. The method of nurseries permits of very rapid multiplication of new varieties, as this is at the rate of eight times in six months, or

4096 times in two years. With the preliminary period of testing at Pasoeroean, which is severe and lasts two or three years, it takes a minimum of five years for a new variety to be extended over 5000-6000 bouws.

An interesting table is given of the changes which have taken place in the varieties grown in 1912, 1919 and 1920. The most marked feature is the diminution of 100 P. O. J. and 247 B (the correct naming of J 247). The increases have been in E. K. 28, D. L. 52 and, to a less extent, in E. K. 2, none of which is found in the 1912 list.

The laying out of the cane field in Java after rice is comparatively well known and is left out here for want of space. It may be mentioned that the rate of converting the sodden paddy land into friable sugar cane soil appears to be little less than miraculous, and seems to be due to the fact that the soil in Java sugar estates does not suffer by being worked wet, but as soon as it dries it becomes friable and well aired. The preparation commences as the paddy harvest is being reaped, and as much as 50 per cent of the trenches and furrows on a 3000-acre estate is completed by the time that the paddy is completely cut. After the furrows and trenches have been finished, the land is left to air for five or six weeks before planting commences. Cultivation is almost entirely done by hand labor, and this alone will preclude any other country from following the system, even if its soil will bear such drastic treatment. Water for irrigation is almost always sparse and the greatest care is necessary to avoid waste: the sets are never flooded, but merely splashed at frequent intervals when recently planted, a proceeding again demonstrating a good labor supply.

Ammonium sulphate is the manure most used, there being usually two doses at three and seven weeks from planting; the manure is placed in small holes on opposite sides of the young plants and covered over. The economic optimum worked out at Pasoeroean is 400 lbs. per acre (80 lbs. N.), but many factories have worked out their own optima, and in some cases have found it to be as much as 550 lbs., in which case the manure is applied in three doses, at three, seven, and eleven weeks from planting. Occasionally phosphates are given, but potash is not needed, and these elements appear to be added to the soil in sufficient quantity by the water irrigating the paddy crop. A case is noted of a dry, coarse, sandy land, where 1500-2250 lbs. of molasses per acre gave useful results by improving the water-holding capacity of the soil.

Details are given in a table of the cost of production of cane, and this is compared with that on two of the chief experimental stations in India. The cost of cane at the factory in Java, on 177 plantations, in 1918 worked out at 4.63 annas (or pence) per standard Indian maund (about 82 lbs.), or one anna less than the Indian examples, which, however, were obviously not strictly comparable.¹

SUPERVISION. This is wholly in the hands of Europeans, whether in fields or factory, and much of the efficiency in the industry is undoubtedly due to this fact. An important part of the European staff is recruited in Holland,

¹ In Chapter II of the Report, the rupee is taken for convenience as the exact equivalent of the guilder, that is at 1s. 8d. On this basis, 4.63 annas equal 5.9 pence. With the rupee at 1s. 4d., as it is at present, the anna exactly equals the penny.

and many of them are graduates of the Agricultural High School at Wageningen or of the Technical High School at Delft. Wherever possible young chemists are employed in the factories for three or four years and then offered posts as assistant managers, and the chance of being promoted to factory managers depends on their ability to master the agricultural side. The Research Station officers, not being Government officials, are interchangeable with those of the factories. An important feature is the great importance attached to the possessions by all higher officials in a factory, whether chemists or engineers, of a knowledge of all branches of factory and plantation work. The average number of Europeans on an estate (factory and plantation) of 1200 bouws (2100 acres) is 20.

FACTORY WORK. The sugar factories in Java are up-to-date, roomy and efficient. They are 186 in number, and of these returns are available from 138 to 145, though engineering details are only available from 77 to 100. Crushing lasts from May to October, with slight variations from these dates in certain districts: the average length of season is 126 days, or just over four months. The canes are brought from the fields in 6-8 ton trucks, which are run alongside the carrier: the contents are hoisted bodily by electric cranes to a sloping platform, from which they are conveyed to a carrier by means of a mechanical rake. Of 77 factories, there are eight with 14-roller mills, eleven 12-roller, twenty-four 11-roller, thirty-three 9-roller, and only one 8-roller.

The sugar house processes are ordinary defecation (lime), sulphitation (lime and sulphurous acid), and carbonatation (lime and carbonic acid); and, in 1919, the proportion of these in the factories were 49 per cent, 38 per cent, and 13 per cent, respectively. Careful boiling and vacuum pan work, together with slow cooling in the crystallizers has, in Java, secured a high yield of sugar and a reduction in the quantity of molasses. The largest factory in Java produced, in 1918, 44,386 tons of sugar, and its progress from 1915 to 1918 is shown in a table from which the following is taken: The cane crushed rose from 362,077 tons to 407,955; the sugar produced from 24,332 tons to 44,386; the parts sucrose in 100 cane from 9.0 to 12.76; the parts sugar obtained per 100 cane from 6.72 to 10.88; and the sugar lost or left in the molasses in 100 cane was reduced from 2.28 parts to 1.88.

"It will be observed," the Committee remarks, "that the cane worked up in 1918 was so much better than that of 1915 and the efficiency of the factory had so much improved that, although only 12.7 per cent more cane was crushed 82.4 per cent more sugar was produced." An interesting indication of the progress made in the workings of the Java factories as a whole is shown in another table, where averages are given of returns from 138 to 143 factories during the same years, the improvement being steadily progressive under each heading from year to year. The fiber was reduced from 13.26 to 12.99 per 100 parts of cane and the parts sucrose increased from 11.63 to 13.63; the purity of the mixed juice rose from 82.0 to 86.5, while the parts glucose per 100 mixed juice fell from 1.32 to 1.0; the purity of the clarified juice rose from 83.5 to 87.9; the parts sugar obtained per 100 parts cane rose from 9.36 to 11.32 and the parts molasses fell from 3.28 to 2.78 (2.73 in 1917); the number of factories working

with cane with 13 parts or more of sucrose per 100 cane rose from 8 to 102 (or 5.80 per cent to 71.33 per cent), and the number of factories working on cane with 10 parts or less sucrose per 100 cane fell from 10 to 0.

LABOR. The matter of labor is simplified by the denseness of the populations. Java, with 50,000 square miles of area, has some 34 millions of people. The labor is entirely voluntary and the present rates are 8 annas for men, $5\frac{1}{2}$ for women, and 4 annas for children. Hence the land-owners secure a reasonable rent for their land together with sufficient continuous employment to yield an income equal to that which they would have got if they cultivated the land themselves; and those who cultivate their own lands have a market for their labor during the milling season. In the factory the skilled labor is usually in the hands of the Chinese, who receive 10 as. to Rs 2 per day, while the unskilled labor is supplied by Javanese at $7\frac{1}{2}$ to 9 annas.

The Committee concludes this chapter on Java as follows: "Whilst there can be no doubt that, as the result of the traditions of the forced culture system, the Java sugar industry has had exceptional advantages in securing land and labor for cane production, it is equally unquestionable that these alone would not have been sufficient to ensure it the commanding position it at present holds. This has been secured by an admirable organization for mutual assistance in all directions, above all in regard to research, generous expenditure in which it is recognized to be a most profitable investment, and by the adoption of methods of cultivation and manufacture on which it would be difficult to improve, carried out under highly trained and well paid supervision. The sugar industry in Java was certainly not in a more favorable position for commanding land and labor in 1918 than in 1894, but whereas the outturn of sugar in 1894 was 2.81 tons per acre, in 1918 it was 4.34 tons. In 1919 it fell to 3.86 tons, but, owing to prolonged drought, the circumstances of the latter year were exceptional. The result is, as Mr. Keatinge, Director of Agriculture in Bombay, stated in 1914, that Java sugar dominates the Eastern markets, and that not only is the industry able to dispense with any protection, subsidy or assistance from Government, but it successfully forces its way through hostile tariffs and pays high dividends on invested capital.

"We have endeavored to give as accurate a picture as possible of the present conditions of the Java sugar industry. It must, however, be remarked in conclusion that many of the conditions are undergoing rapid and material change. Costs of both cultivation and manufacture are rising, labor difficulties are increasingly felt, and political developments threaten to affect the hitherto amicable relations between the factories and the land-owners. The industry is thus not entirely secure in the position it has so successfully established, and its difficulties and problems appear likely to multiply rather than to diminish in the years that lie before it."

[J. A. V.]

Annual Synopsis of Mill Data 1921.

By W. R. McALLEN.

Data from 40 factories appear in this Synopsis. But one factory in the Association did not report. This omission does not affect the averages, as the sugar produced at this factory was less than 0.2% of the total crop. This Synopsis does fall short of representing the 1921 crop, however, because the harvest has been prolonged. Six factories only had finished grinding on October 1, the latest date on which reports for this Synopsis could be made. Fifteen per cent of the crop was still unground on this date.

The general arrangement of the large tables is the same as in the last three or four years, the factories being listed in the order of the size of the crop, taking as a basis the average of the preceding five seasons. The first of the large tables contains the analytical data, losses, recoveries, etc. True averages, together with the averages for the preceding nine seasons, also appear. The second and third of the large tables are compiled so that engineers may have details of the settings, grooving, speed, etc., of all of the factories. The second table is a compilation of knife, roller and returner bar data, speed of the rollers and pressure. Surface and juice grooving in use this season appear in the third table.

Varieties of Cane.

The proportion of the principal varieties of cane ground at the different factories and true averages for the preceding three seasons appear in Table 1.

The tonnage of Lahaina has decreased till it now holds second place by a narrow margin. One-half of the factories ground H 109 in quantities amounting to 1% or more of their crop. The tonnage of this variety has increased till it is now in third place, having passed D 1135, though the latter variety shows a material increase over previous years. The proportion of Yellow Caledonia is larger than last season. The variation is apparently on account of the bi-yearly harvest. The tonnage of Tip canes has decreased.

Of the minor varieties included in the column "Other Varieties," those that formed 1% or more of the crop of any plantation are:

Variety—	% of Total Crop.
Rose Bamboo	1.02
H 146	0.93
H 20	0.23
H 227	0.17
Yellow Bamboo	0.14
White Bamboo	0.10
H 223	0.05
Badila	0.04
	<hr/>
	2.68

TABLE NO. 1.
VARIETIES OF CANE.

	Yellow Caledonia.	Lahaina.	H 109.	D 1135.	Striped Tip & Yellow Tip.	Striped Mexican.	D 117.	Other Varieties.
H. C. & S. Co.....	..	42	49	8	..	..	..	1
Oahu .....	..	39	33	20	..	..	..	8
Ewa	1	38	59	..	..	..	..	2
Maui Agr. ....	..	49	36	6	..	..	..	9
Pioneer .....	..	40	6	11	..	41	..	2
Waialua	22	28	9	14	..	..	..	27
Haw. Sug.	5	21	19	43	..	..	..	12
Olaa	90	..	..	8	..	..	..	2
Honolulu	59	19	17	5	..	..	..	..
Onomea	96	..	..	1	3	..	..	..
Kekaha .....	..	72	4	18	..	..	..	6
Hakalau	100	..	..	..	..	..	..	..
McBryde	31	2	34	33	..	..	..	..
Hilo	95	..	..	5	..	..	..	..
Lihue	95	..	3	1	..	..	..	1
Haw. Agr.	56	..	..	17	..	8	..	19*
Wailuku	1	29	30	5	..	29	..	6
Makee	100	..	..	..	..	..	..	..
Honokaa	10	..	10	66	14	..	..	..
Laupahoehoe ..	56	..	..	3	33	..	8	..
Waiakea	100	..	..	..	..	..	..	..
Kahuku	50	17	33	..	..	..	..	..
Pepeekeo	100	..	..	..	..	..	..	..
Koloa	89	7	4	..	..	..	..	..
Hamakua	50	..	1	14	4	..	30	1
Paaupau	53	..	2	36	4	..	3	2
Honomu	97	..	..	..	..	..	3	..
Hawi	54	..	10	4	32	..	..	..
Hutchinson	43	..	..	..	3	..	..	54†
Kaeleku	100	..	..	..	..	..	..	..
Kaiwiki	66	..	..	2	4	..	27	1
Waianae .....	..	59	35	1	..	2	..	3
Kilauea	100	..	..	..	..	..	..	..
Kohala	40	..	..	18	42	..	..	..
Waimanalo	100	..	..	..	..	..	..	..
Niuli	78	..	..	..	22	..	..	..
Halawa	36	..	..	5	59	..	..	..
Olowalu .....	..	58	37	..	..	5	..	..
Union Mill	38	..	..	7	55	..	..	..
Kipahulu	100	..	..	..	..	..	..	..
True Average 1921.....	45.1	17.4	15.0	11.0	3.0	3.0	1.1	4.4
“ “ 1920.....	42.7	26.7	9.1	10.0	3.5	2.5	1.0	4.5
“ “ 1919.....	46.4	29.1	6.8	7.2	2.9	1.8	1.1	4.7
“ “ 1918.....	42.9	37.9	4.0	7.5	2.0	0.6	0.8	4.3

* White and Yellow Bamboo 7%.

† Rose Bamboo.

TABLE NO. 2.
COMPOSITION OF CANE BY ISLANDS.

	Hawaii	Maui	Oahu	Kauai	Whole Group
1912					
Polarization	13.30	16.00	14.38	14.06	14.34
Percent Fiber	13.53	11.53	12.62	12.59	12.67
Purity 1st Mill Juice	88.40	91.13	88.46	88.30	89.04
1913					
Polarization	13.22	15.56	14.21	13.70	14.05
Percent Fiber	13.74	11.73	12.75	12.50	12.85
Purity 1st Mill Juice	88.47	91.11	88.20	88.12	89.02
1914					
Polarization	12.75	15.16	14.23	13.62	13.78
Percent Fiber	13.62	11.59	12.44	12.75	12.74
Purity 1st Mill Juice	88.22	91.02	88.11	87.51	88.71
1915					
Polarization	12.61	15.23	14.29	14.09	13.77
Percent Fiber	13.00	11.44	12.77	12.46	12.51
Purity 1st Mill Juice	87.86	90.48	87.27	86.99	88.24
1916					
Polarization	12.54	14.62	13.74	13.26	13.45
Percent Fiber	13.22	12.22	12.51	12.86	12.74
Purity 1st Mill Juice	87.56	89.41	87.15	86.26	87.70
1917					
Polarization	13.31	15.43	13.55	13.13	13.76
Percent Fiber	13.23	11.67	12.25	12.89	12.62
Purity 1st Mill Juice	88.11	90.69	86.86	86.70	88.02
1918					
Polarization	11.88	14.25	13.50	12.54	12.97
Percent Fiber	13.35	11.53	12.23	12.84	12.50
Purity 1st Mill Juice	87.27	88.62	86.93	85.88	87.18
1919					
Polarization	12.74	15.12	14.24	13.52	13.74
Percent Fiber	13.07	11.74	12.14	12.61	12.49
Purity 1st Mill Juice	87.54	88.81	87.00	85.82	87.34
1920					
Polarization	12.86	15.29	13.75	13.07	13.64
Percent Fiber	13.36	11.39	12.65	12.72	12.64
Purity 1st Mill Juice	87.87	88.94	85.40	86.52	87.24
1921					
Polarization	12.25	14.67	13.72	12.67	13.12
Percent Fiber	13.28	11.82	12.40	13.28	12.80
Purity 1st Mill Juice	87.18	87.37	85.46	84.07	86.22

H 245 was ground in approximately the same quantities as Badila, but did not constitute 1% of the crop at any one plantation.

Quality of Cane.

In quality the cane was much poorer than last year. The purity of the first mill juice was lower by some one per cent than in any year for which figures are available. The polarization was lower than in any year except 1918. Judging by the quality ratio, the cane was slightly better than the low point reached in 1918, but poorer than in any other year. The fiber content was higher than in other years except 1911 and 1913. Delayed harvesting has been responsible to a large extent for the poorer quality of the cane.

The composition of the cane by islands is shown in Table 2. In quality of cane, the different islands are in the same relative order as in previous years; that is Maui, Oahu, Kauai and Hawaii. Both polarization and purity show a large decrease compared with last year on all islands, except Oahu. On this island the delayed harvesting conditions were somewhat similar to those of the preceding season and the decrease in the quality of the cane is small.

Milling.

A reduction in the average milling loss of from 2.75 to 2.64 indicates a continuation of the improvement in milling. The extraction has not kept pace with the reduction in milling loss because of higher fiber in the cane, and instead of being higher is actually 0.02 lower than last year.

The polarization of the bagasse has decreased from year to year. This has continued during this season.

The same has been true of the moisture content of the bagasse in previous years. This year, however, for the first time since the figures have been averaged, the moisture content of the bagasse is higher than it was the preceding season. The increase is not great, the figures being 41.05 and 41.20. If we class the first twenty factories in the tabulations as the larger and the last twenty as the smaller, we find that this increase is due to the work of the smaller factories, the average for the larger factories being the same as last year.

The amount of maceration has again decreased, and is now 1.5 below the maximum reached in 1919. Over 60% of the factories report decreased maceration.

While methods for determining the efficiency of the maceration are far from satisfactory, there is ample evidence to indicate that it is low. If the efficiency of the maceration can be increased the amount used can be reduced without detracting from the work. It is probable that with a given sucrose extraction, an increase in the efficiency of the maceration will decrease the extraction of impurities. This is a subject worthy of the attention of the engineers.

New records have been established this season in both milling loss and extraction. Table 3 shows the factories ranked according to milling loss. Two factories, Onomea with 1.16 and H. C. & S. Co. with 1.25 have exceeded the record for milling loss of 1.27 made last year by Maui Agricultural Co. H. C. & S. Co. has also established a new record for extraction, finishing the season

TABLE NO. 3.—MILLING RESULTS.

Showing the Rank of the Factories on the Basis of Milling Loss.

Factory	Milling Loss	Extraction Ratio	Extraction	Equipment
1. Onomea	1.16	0.09	98.81	2RC60,S54,12RM66
2. H. C. & S. Co. ..	1.25	0.08	99.07	K(2),2RC78,S72,15RM78
3. Maui Agr.	1.35	0.10	98.90	K(2),21RM66
4. Hakalau	1.37	0.11	98.62	2RC54,12RM9-60,3-66
5. Hilo	1.44	0.11	98.47	K,2RC60,12RM66
6. Pepeekeo	1.83	0.15	98.09	2RC54,9RM60
7. Makee	2.12	0.18	97.46	K,2RC72,S72,9RM72
8. Ewa	2.13	0.15	98.14	K(2),20RM78
9. Wailuku	2.18	0.16	98.08	K,2RC72,12RM78
10. Honomu	2.19	0.17	97.79	2RC60,9RM60
11. Paaauhau	2.21	0.19	97.29	2RC60,12RM66
12. Koloa	2.28	0.19	97.29	K,2RC60,12RM66
13. Haw. Sug.	2.38	0.17	98.05	K,2RC72,S72,12RM78
14. Lihue	2.50	0.21	97.10	K,2RC78,S72,12RM78
15. Honokaa	2.57	0.24	96.91	K(2),14RM2-60,12-66
16. Haw. Agr.	2.62	0.23	96.94	3RC60,12RM66
17. Kilauea	2.73	0.24	96.66	K,S,3RC60,9RM60
18. Pioneer	2.81	0.19	97.84	K,2RC72,S72,15RM72
19. Laupahoehoe ...	2.81	0.22	97.01	K,2RC60,9RM60
20. McBryde	2.89	0.23	96.80	K,2RC72,S54,9RM84
21. Waianae	2.92	0.21	97.34	K(2),12RM60
22. Olaa	3.06	0.25	96.83	K,S72,12RM78
23. Hawi	3.08	0.23	97.14	K(3),3RC48,12RM3-48,9-54,14RM54
24. Olowalu	3.09	0.24	97.04	K,3RC48,9RM48
25. Waialua	3.16	0.22	97.40	K(2),14RM78
26. Kekaha	3.16	0.22	97.24	2RC54,9RM60
27. Hutchinson	3.26	0.28	96.31	2RC60,9RM60
28. Honolulu	3.28	0.24	97.00	K(2),S54,11RM78
29. Kahuku	3.34	0.27	95.71	3RC60,S54,9RM72
30. Oahu	3.57	0.26	96.95	K(2),2RC78(2),S72,12RM78(2)
31. Kohala	3.67	0.30	95.92	K(2),12RM60
32. Kaiwiki	3.79	0.30	95.55	K,2RC60,9RM60
33. Kaeleku	3.84	0.34	95.35	K(2),11RM2-54,9-60
34. Waiakea	4.20	0.33	95.41	K,S42,11RM60
35. Hamakua	5.31	0.41	94.13	K,2RC60,12RM60
36. Halawa	6.03	0.54	92.49	K,2RC60,6RM50
37. Union Mill	6.50	0.55	91.53	K,9RM60
38. Niuli	8.50	0.71	89.86	K(2),9RM54
39. Kipahulu	9.02	0.73	89.85	K,5RM3-42,2-54

with an average of 99.07. Five factories have reported milling losses of less than 1.5, against a maximum of two in any previous year. Compared with 1920, Ewa, Wailuku, Honokaa, Koloa, Hawi and Makee have advanced materially in their relative standing. These factories have also made material reductions in their milling loss. Olowalu, Kekaha, Kilauea, Waianae, Oahu and Pioneer are this year materially lower in their relative standing.

Gravity Solids and Sucrose Balances.

Table No. 4 shows these balances for the factories reporting the necessary data. As in previous years where suspended solids in the mixed juice has not been given it has been estimated at 0.25%.

The use of sucrose figures eliminates several errors that exist in the ordinary control based on polarization. These methods have been improved and simplified so that satisfactory determinations may be made by laboratory assistants. At the recent meeting of the Hawaiian Chemists' Association, estimates of the time required for the extra determinations varied from half an hour to an hour and a half a day. Twenty-one factories, manufacturing 65% of the crop, have this year made the necessary determinations. It would appear to be but a short step, yet a very desirable one, for this to be done by the remaining factories, thus putting the control on the much more reliable sucrose basis.

Boiling House Recovery.

The recovery compared with the available calculated from the analysis of the syrup appears in Tables 5 and 6. These tables are principally a check on the chemical control. It is necessary in calculating Table 5 to make the assumptions explained in the note at the bottom of the table. These assumptions, while true for average conditions, are not necessarily exact for individual cases. Comparisons over a number of years indicate that inaccuracies thus introduced are probably not over one per cent and that a figure of over 101% indicates errors in the control. Figures under 99 may indicate errors in the control or actual losses. There would seem to be no reason, other than errors in the control, why the figure for available based on true sucrose in Table 6 should be over 100.

But one factory is over 101% in Table 5, and but two over 100% in Table 6. This is a better showing than in any previous year and an indication of improvement in the chemical control.

Molasses Produced on Theoretical.

This Table No. 7 has again been included. The figures this year are considerably more consistent than last season. As has been previously explained this table has been calculated on gravity solids. Using this basis, the only one available, a discrepancy is introduced which makes the molasses accounted for less than the calculated theoretical. It is probable that from 85% to 95% of the theoretical amount should be accounted for.

Examination of the figures shows that 10 factories have reported less than

TABLE NO. 4.
GRAVITY SOLIDS AND SUCROSE BALANCES.

Factory	GRAVITY SOLIDS PER 100 GRAVITY SOLIDS IN MIXED JUICE				SUCROSE PER 100 SUCROSE IN MIXED JUICE			
	Press Cake	Commercial Sugar	Final Molasses	Undeter- mined	Press Cake	Commercial Sugar	Final Molasses	Undeter- mined
H. C. & S. Co.....	5.7	74.7	16.6	3.0	0.5	89.4	7.6	2.5
Oahu.....	3.9	74.8	19.0	2.3	0.2	89.2	9.4	1.2
Ewa.....	5.8	67.9	23.1	3.2	0.3	85.5	11.1	3.1
Maui Agr.	5.4	75.4	20.2	— 1.0	0.2	90.3	9.5	0.0
Pioneer.....	2.7	75.1	20.2	2.0	0.2	89.3	9.1	1.4
Waialua.....	7.9	66.2	26.0	5.3	0.3	82.9	11.0	5.8
Onomea.....	5.1	77.3	15.6	2.0	0.1	91.7	6.8	1.4
Hakalau.....	3.7	79.7	14.5	2.1	0.2	92.8	6.4	0.6
Hilo.....	4.1	79.7	13.8	2.4	0.2	92.7	6.0	1.1
Haw. Agr.	3.4	73.9	20.2	2.5	0.1	86.9	9.4	3.6
Wailuku.....	3.0	72.4	22.8	1.8	0.2	87.0	10.8	2.0
Makee.....	2.1	67.6	23.7	6.6	0.3	83.7	11.9	4.1
Laupahoehoe.....	4.3	75.2	19.9	0.6	0.1	88.3	9.7	1.9
Waialea.....	4.5	73.3	17.6	4.6	0.3	87.5	9.1	3.1
Pepeekeo.....	4.3	76.5	16.5	2.7	0.2	91.5	7.2	1.1
Hamakua.....	3.9	70.4	9.4	16.3	0.5	83.7	4.6	11.2
Paauhau.....	7.6	73.2	18.1	1.1	0.4	90.2	8.4	1.0
Honolulu.....	5.2	77.9	15.4	1.5	0.3	92.4	6.6	0.7
Hutchinson.....	3.2	74.3	13.4	9.1	0.3	86.1	6.8	6.8
Kilauea.....	2.9	62.9	24.4	9.8	0.5	79.4	13.1	7.0
Kohala.....	7.8	72.8	16.1	3.3	0.3	90.5	8.0	1.2

80% of the theoretical amount of molasses. All of these factories have undetermined losses larger than the average. But three factories reporting over 80% of the theoretical amount of molasses have undetermined losses of over 2%.

Boiling House Work.

During the seven years for which average increases in purity from mixed juice to syrup are available these figures have shown an almost continuous decrease. The present average, 1.13, is 0.20 below the previous low point reached last year. Milling practice has changed materially in these seven years, and without doubt an increased amount of fine cuss cuss now passes the mill screens and enters the boiling house with the mixed juice. During clarification a part of this cuss cuss is dissolved, adding to the impurities in the juice and diminishing the increase in purity. Screening practice is in need of revision to meet this new condition and insure the recovery of the extra sugar extracted by improved milling.

This season delays have also diminished the increase in purity and added to the losses. Such losses are due to the development of micro-organisms in liquors cooling to the point where such development can take place and to chemical inversion in liquors that are not sufficiently alkaline. Though such losses cannot be entirely avoided during delays, they can be reduced to less than what the writer has frequently observed, by maintaining temperatures in the settling tanks, filter presses and even in the syrup tanks above the point where micro-organisms can develop and keeping the products sufficiently alkaline so that chemical inversion will not take place.

Though experimental work has not yet covered a sufficiently wide variety of cases to estimate the possible increase in purity, it is safe to state that the present average can be materially improved.

The lime used in clarification was slightly in excess of the amount used the previous season.

The polarization of the press cake has increased slightly, while the weight has decreased in somewhat greater proportion, resulting in a slightly lower loss per cent cane. Due to the lower polarization of the latter, however, the loss per cent polarization of cane shows a slight increase.

It is improbable that the small loss reported in the press cake represents all the loss at this point. It is not easy to maintain temperature conditions in the presses that will prevent bacterial growth. More often than not there is evidence of bacterial development during washing, if not indeed during filtration itself. The writer is convinced that the actual loss is usually much greater than that indicated by the analysis of the washed cake.

While the syrup was evaporated to a higher density than last season, this point was not as high as has been reached in several previous years.

The polarization of the commercial sugar has increased from 96.36 to 96.75, changed marketing conditions having made this increase profitable. Higher polarization has depressed the boiling house recovery 0.17. This is not, however, a loss as it has been taken into consideration in calculating the most profitable polarization.

TABLE NO. 5.
APPARENT BOILING-HOUSE RECOVERY.

Comparing percent available sucrose in the syrup (calculated by formula) with percent polarization actually obtained.

Factory	Available *	Obtained	Recovery on Available
H. C. & S. Co.....	91.57	90.92	99.29
Oahu	89.48	90.35	100.97
Ewa	88.23	86.50	98.04
Maui Agr.	91.25	90.49 †	99.17
Pioneer	90.70	89.43	98.60
Waialua	88.35	83.62	94.65
Haw. Sug.	91.38	91.21	99.81
Olaa	90.15	90.26	100.12
Onomea	92.08	92.19	100.12
Kekaha	89.93	88.46	98.37
Hakalau	92.37	92.97	100.65
McBryde	86.93	83.94	96.56
Hilo	93.25	92.82	99.54
Lihue	86.38	85.77	99.29
Haw. Agr.	90.87	87.56	96.36
Wailuku	88.89	87.63	98.58
Makee	85.37	84.46	98.93
Honokaa	87.13	85.56	98.20
Laupahoehoe	91.15	89.38	98.06
Waiakea	89.30	87.97	98.51
Kahuku	87.58	74.68	85.27
Pepeekeo	91.62	92.15	100.58
Koloa	87.29	86.70	99.32
Hamakua	89.83	84.62	94.20
Paaauhau	91.47	90.33	98.75
Honomu	92.88	93.14	100.28
Hawi	91.09	81.27	89.22
Hutchinson	90.03	87.12	96.77
Kaeleku	87.27	86.93	99.61
Kaiwiki	90.22	90.24	100.02
Waianae	88.28	87.62	99.25
Kilauea	82.36	80.36	97.57
Kohala	90.10	91.29	101.32
Niulii	89.80	88.95	99.05
Halawa	88.57	78.04	88.11
Olowalu	87.44	86.29	98.68
Union Mill	87.32	80.81	92.54
Kipahulu	90.99	88.68	97.46

* In order to calculate the available sucrose it is necessary to estimate the gravity purity of the syrup and sugar. Data from factories determining both apparent and gravity purities indicate that the average correction necessary is the addition of 0.8 to the apparent purity of the syrup and 0.3 to the apparent purity of the sugar. When the moisture in the sugar has not been reported 1% has been taken. 38 has been used when the gravity purity of the molasses has not been reported.

† Sucrose.

The moisture content of the sugar has decreased from 0.97 to 0.92%. This decrease is not in proportion to the increase in polarization. A moisture content of 0.92% in such sugar is dangerously near the point where deterioration may be expected.

The gravity purity of the final molasses has decreased from 38.75 to 38.53. This is a better purity than in any year except 1919, when the average was 37.95. Compared with last year, better low grade work has had a favorable influence on the recovery to the extent of 0.10.

Last year both mixed juice and syrup were lower in purity than in any previous year. This year the mixed juice was 1.10 and the syrup 1.30 below the low points reached a year ago. A large increase in the molasses loss and a large decrease in the recovery has resulted. The following figures for the last three seasons indicate, however, that the decrease in recovery is greater than is accounted for by lower syrup purities. The average difference between apparent and gravity purities has been assumed to be the same as the average of the factories reporting both in calculating the figures for available.

Year	Available	Recovery	Recovery on Available
1919	91.87%	90.96%	99.01%
1920	91.17	89.56	98.23
1921	89.87	88.03	97.95

Increased undetermined losses have been the principal factors in the above decrease of recovery on available.

Factory Efficiency.

As there has been some misunderstanding regarding this table, the writer will quote Dr. Norris in the Annual Synopsis for 1914: "Since the object of the factory work is to transfer as much as possible of the available sugar in the cane into the bag, the extent to which it does this represents its efficiency. . . . In arriving at an accurate standard of comparison it seems to me fair, as was done by Mr. Deerr, to assume 100% extraction at the mills. . . . A gravity purity of 35 is assumed as possible in all cases." And from the 1915 Synopsis: "The calculated results are intended as an approximate gauge of the quality of the factory work."

Since the table was first published the following changes have been made: The standard for molasses purity has been reduced from 35 to 30, because it is now known that molasses can be crystallized to at least the latter point. It was at first estimated that at least one per cent increase in purity from mixed juice to syrup should be secured. The increase is now taken as it is reported, though actually many factories ought to be penalized on this score.

It should be noted that the first column is the extraction. If the fiber in the cane increases the extraction may decrease even though the same milling loss is maintained. In the same way a decrease in syrup purity will cause a lower

TABLE NO. 6.
TRUE BOILING-HOUSE RECOVERY.
Comparing percent sucrose available and recovered.

Factory	Available	Obtained	% Recovery on Available
H. C. & S. Co.....	91.70	89.85	97.98
Oahu	89.59	89.38	99.77
Ewa	88.32	85.76	97.10
Maui Agr.	91.25	90.48	99.16
Pioneer	90.34	89.48	99.05
Waialua	88.39	83.15	94.07
Onomea	92.67	91.79	99.05
Hakalau	92.35	92.99	100.69
Hilo	92.91	92.89	99.98
Haw. Agr.	91.04	86.99	95.55
Wailuku	88.98	87.17	97.97
Makee	85.20	83.95	98.53
Laupahoehoe	91.19	88.39	96.93
Waiakea	89.02	87.77	98.60
Pepeekeo	91.68	91.68	100.00
Hamakua	89.64	84.12	93.84
Paaupau	91.31	90.56	99.18
Honomu	92.75	92.68	99.92
Hutchinson	90.31	86.36	95.63
Kilauea	82.82	79.80	96.35
Kohala	90.16	90.77	100.68

TABLE NO. 7.
PERCENT MOLASSES PRODUCED ON THEORETICAL.

H. C. & S. Co.....	86.2	Honokaa	84.6
Oahu	90.9	Laupahoehoe	98.8
Ewa	88.1	Waiakea	79.0
Maui Agr.	105.2	Kahuku	72.2
Pioneer	91.2	Pepeekeo	85.9
Waialua	79.4	Koloa	87.3
Haw. Sug.	86.2	Hamakua	36.9
Olaa	91.2	Paaupau	93.9
Honolulu	96.9	Honomu	93.1
Onomea	83.6	Hutchinson	59.5
Kekaha	93.8	Kaeleku	88.4
Hakalau	85.2	Kaiwiki	90.2
McBryde	99.4	Kilauea	71.1
Hilo	85.4	Kohala	84.6
Lihue	77.7	Niulii	99.6
Haw. Agr.	89.0	Olowalu	74.8
Wailuku	92.5	Union Mill	73.5
Makee	78.6		

figure in column two even though the undetermined loss and the gravity purity of the molasses remain the same, provided the purity of the latter is above 30.

It would be desirable, in addition to this table, to rank the factories on a basis that would equitably allow for variations in the fiber, possible increase in purity from mixed juice to syrup, syrup purity, etc. So far the writer has not been able to devise a method for expressing this on a percentage, or indeed any other, basis.

Through the courtesy of this Association the tabulated matter in this Synopsis was presented at the recent annual meeting of the Hawaiian Chemists' Association. At this meeting suggestions made regarding the Synopsis included indicating exactly what was reported as "first mill" and "last mill" juice, and omitting the calculations per cent cane and per ton of cane from Table No. 9 and the large table.

The calculations in this Synopsis have been made by A. Brodie and W. L. McCleery.

TABLE NO. 8.
FACTORY EFFICIENCY.

Showing the rank of the factories, comparing their recovery with the calculated recovery resulting from 100% extraction, reducing the molasses to 30 gravity purity, and eliminating all other losses. Factories reporting a recovery of over 101% of the available (Table No. 5) are omitted from this tabulation.

No.	Factory	Milling	Boiling House	Over All
1	Onomea	98.81	98.03	97.01
2	Hakalau	98.62	98.15	96.96
3	Pepeekeo	98.09	98.36	96.56
4	Honomu	97.79	98.22	96.40
5	Hilo	98.47	97.47	96.11
6	H. C. & S. Co.	99.07	96.26	95.54
7	Maui Agr.	98.90	96.10	95.20
8	Pioneer	97.84	95.72	93.95
9	Oahu	96.95	96.59	93.90
10	Olaa	96.83	96.20	93.59
11	Paaunau	97.29	95.89	93.50
12	Haw. Sug.	98.05	97.06	93.26
13	Wailuku	98.08	94.61	92.97
14	Waianae	97.34	95.01	92.72
15	Ewa	98.14	94.19	92.71
16	Koloa	97.29	94.89	92.64
17	Kaiwika	95.55	95.97	92.03
18	Lihue	97.10	94.42	91.93
19	Laupahoehoe	97.01	94.52	91.91
20	Kekaha	97.24	94.23	91.80
21	Olowalu	97.04	93.88	91.37
22	Makee	97.45	92.94	90.91
23	Haw. Agr.	96.94	93.19	90.45
24	Kaeleku	95.35	94.18	90.14
25	McBryde	96.80	92.42	89.68
26	Honokaa	96.91	92.09	89.51
27	Waiakea	95.41	93.48	89.46
28	Hutchinson	96.31	92.13	89.03
29	Waiialua	97.40	89.54	87.43
30	Kilauea	96.66	89.36	86.67
31	Niulii	89.86	94.49	85.26
32	Hamakua	94.13	90.02	84.99
33	Kipahulu	89.85	93.27	84.08
34	Hawi	97.14	86.31	84.05
35	Union Mill	91.53	86.57	79.66
36	Kahuku	95.71	82.22	79.07
37	Halawa	92.49	82.71	76.73

TABLE NO. 9.
SUMMARY OF LOSSES.

FACTORY	POUNDS POLARIZATION PER TON OF CANE				POLARIZATION PER 100 CANE				POLARIZATION PER 100 POLARIZATION OF CANE				FACTORY
	Baggasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	Baggasse	Press Cake	Molasses	Other Known	Undetermined	TOTAL	
H. C. & S. Co.	3.0	1.6	23.6	...	4.2	32.4	0.15	0.08	1.18	...	0.21	1.62	H. C. & S. Co.
Oahu	8.6	0.6	26.2	...	0.4	35.8	0.43	0.03	1.31	...	0.29	1.79	Oahu
Ewa	5.0	0.8	29.2	...	5.8	40.8	0.25	0.04	1.46	...	0.02	2.04	Ewa
Maul Agr.	3.2	0.6	26.8	...	0.0	30.4	0.16	0.03	1.33	...	0.00	1.52	Maul Agr.
Pioneer	6.4	0.6	26.8	...	4.2	38.0	0.32	0.03	1.34	...	0.21	1.90	Pioneer
Waialua	7.4	0.8	30.6	...	14.4	53.2	0.37	0.04	1.53	...	0.72	2.66	Waialua
Haw. Sug.	5.6	1.8	21.8	0.2	2.6	32.0	0.28	0.09	1.09	0.01	0.13	1.60	Haw. Sug.
Olaa	7.8	1.0	21.6	...	1.4	31.8	0.39	0.05	1.08	...	0.07	1.59	Olaa
Honolulu	8.0	0.4	37.2	0.8	...	...	0.40	0.02	1.86	0.04	...	...	Honolulu
Onomea	2.8	0.2	16.6	...	2.4	22.0	0.14	0.01	0.83	...	0.12	1.10	Onomea
Kekaha	7.8	1.6	27.8	...	3.6	40.8	0.39	0.08	1.30	...	0.18	2.04	Kekaha
Hakaha	3.6	0.6	16.2	...	1.8	21.8	0.18	0.03	0.81	...	0.07	1.09	Hakaha
McBryde	8.0	0.4	31.8	...	3.8	47.0	0.40	0.02	1.74	...	0.19	2.35	McBryde
Hilo	4.0	0.4	13.4	1.8	2.8	22.6	0.20	0.02	0.77	...	0.14	1.13	Hilo
Lihue	6.8	1.2	24.8	...	5.8	40.4	0.34	0.06	1.24	0.09	0.39	2.02	Lihue
Haw. Agr.	7.0	0.4	21.4	...	6.6	38.8	0.35	0.02	1.07	...	0.33	1.77	Haw. Agr.
Waialuku	5.4	0.4	30.2	...	3.8	39.8	0.27	0.02	1.51	...	0.19	1.89	Waialuku
Mahee	5.8	0.8	27.2	...	7.8	41.6	0.29	0.04	1.36	...	0.39	2.34	Mahee
Honokaa	6.6	1.0	24.8	...	5.6	37.6	0.33	0.05	1.22	...	0.28	1.88	Honokaa
Laupahoehoe	7.4	0.2	23.8	...	2.0	33.4	0.37	0.01	1.39	...	0.10	1.67	Laupahoehoe
Waiakea	11.8	0.6	22.4	...	7.0	41.8	0.59	0.03	1.12	...	1.51	3.60	Waiakea
Kahuku	10.8	1.0	30.0	...	30.2	72.0	0.54	0.05	1.50	...	0.20	1.95	Kahuku
Pepeekeo	4.6	0.6	17.2	...	1.6	24.0	0.23	0.03	0.86	...	0.32	1.27	Pepeekeo
Koloa	6.6	1.0	27.4	...	4.0	39.0	0.33	0.05	1.37	...	1.32	2.72	Koloa
Paahau	15.4	1.2	11.4	...	26.4	54.4	0.77	0.06	0.57	...	0.13	1.43	Paahau
Honoumuli	6.2	0.8	19.0	...	2.6	28.6	0.31	0.04	0.95	...	0.02	1.15	Honoumuli
Hawi	5.6	0.6	16.4	...	0.4	23.0	0.28	0.03	0.82	...	2.37	2.79	Hawi
Hutchinson	8.6	0.6	15.4	...	47.4	55.8	0.37	0.05	...	...	0.16	1.98	Hutchinson
Kaeleku	10.4	1.4	24.6	...	13.4	39.6	0.52	0.07	1.23	...	0.08	1.79	Kaeleku
Kaewiki	11.2	1.2	21.8	...	3.2	39.6	0.56	0.06	1.09	...	0.67	2.09	Kaewiki
Walanae	7.4	1.0	29.2	...	1.6	35.8	0.37	0.05	1.46	...	1.67	2.99	Walanae
Kilauea	7.6	1.2	23.2	...	33.4	51.8	0.38	0.06	1.46	...	0.68	2.59	Kilauea
Kohala	9.8	0.8	18.6	...	13.8	30.8	0.49	0.04	0.93	...	0.08	1.54	Kohala
Waimanalo	...	1.2	...	...	1.6	...	...	0.06	...	...	...	...	Waimanalo
Niuli	24.4	1.4	23.0	...	...	...	1.22	0.07	...	...	...	2.48	Niuli
Halawa	16.8	1.4	...	...	0.8	49.6	0.84	0.07	1.15	...	0.04	1.14	Halawa
Olowahu	7.8	0.8	25.2	...	45.4	63.6	0.39	0.04	1.26	...	2.27	3.18	Olowahu
Union Mill	20.2	1.2	25.4	...	9.6	43.4	0.10	0.06	1.27	...	0.48	2.17	Union Mill
Kipahulu	25.0	3.2	...	...	16.2	63.0	1.01	0.16	1.26	...	0.81	3.15	Kipahulu
					24.6	52.8	1.25	0.16	...	...	1.23	2.64	

* A comparison of the available sucrose in the juice with the amount recovered in the boiling-house indicates that there is probably an error in some of the results reported from this factory.
† Sucrose.

Sugar Prices for the Month

Ended December 15, 1921.

(96° Centrifugals)		
	Per Lb.	Per Ton.
(Nov. 15, 1921)	4.11c	\$ 82.20
[1] " 19	4.09375	81.875
[2] " 21	3.9925	79.85
[3] " 22	4.11	82.20
[4] Dec. 8	3.98	79.60
[5] " 13	3.86	77.20
[6] " 14	3.765	75.30
[7] " 15	3.67	73.40
Average for the month.	3.94	78.95

-
- [1] St. Croix 3.9375. Venezuela 4.25.
 - [2] Cubas 4.11. Porto Ricos 3.875.
 - [3] Cubas.
 - [4] Cubas.
 - [5] Spot Cuba.
 - [6] Old crop 3.86; new crop 3.3.67.
 - [7] New crop Cubas.

ANNUAL SYNOPSIS OF MILL DATA--SHOWING RESULTS FROM 40 HAWAIIAN FACTORIES FOR CROP OF 1921

* Sucrose.
† Refined sugar.
‡ For one mill only.
§ Probably influenced by low-grade sugar in the syrup
¶ 1921 crop unfinished.

CANE MILL DATA, SEASON OF 1921

CANE MILL DATA, SEASON OF 1921 (CONTINUED) ROLLER GROOVING

